THE ROOT SYSTEM OF VINES ON A FERTILIZATION EXPERIMENT WITH SPECIAL REFERENCE TO THE PHOSPHATE STATUS OF THE SOIL.

by

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INDEX.

CHAPTER I.	Introduction.
CHAPTER II.	Description of the Experimental Block & Methods of Investigation.
CHAPTER III.	The Response of Vine Roots to Fertilization.
CHAPTER IV.	Shoot Development on the B & C Blocks and the Relationship to the Root Development and the Crop Production.
CHAPTER V.	The Citric Acid Soluble fraction of the Soil Phosphate.
CHAPTER VI.	NH_4 F-HCl Soluble Phosphate, Total N and pH.
CHAPTER VII.	The Phosphate Economy of Block C.

THE ROOT SYSTEM OF VINES ON A FERTILIZATION EXPERIMENT WITH SPECIAL REFERENCE TO THE PHOSPHATE STATUS OF THE SOIL.

INTRODUCTION.

In 1938 Dr. M. S. du Toit, then Director of the W. P. F. R. S., laid out at Bien Donne a Vineyard Fertilization experiment in order to determine the degree of response of the vine to the Nutrients Nitrogen, Phosphate and Potash. The idea was also to determine the role played by irrigation, but as this would have entailed the sealing off of plots if the treatments were to be randomly distributed on the same block of soil. Thus the experiment was split into two; unirrigated and irrigated, each with a similar series of fertilization treatments. For details of the lay out see Chapter II.

The motive behind this experiment was the realisation that with the gradual reduction of livestock on the farms due to the increased mechanisation, insufficient manure was available for fertilization purposes. Further it was obvious that this position would worsen, rather than improve, and thus it was imperative to know what the effects of inorganic fertilization would be. Although organic material is the ideal fertilizer, lack of this means that inorganic fertilizers must be used as substitutes.
Further in the pursuit of basic knowledge regarding plant nutrition it is only possible to obtain results when the exact amounts of nutrient minerals in the material added is known which in the case of organic manures is difficult to assess.

The experiment provides thus an object lesson in the effects of nothing but inorganic fertilization as well as supplying valuable information as to the basic nature of plant nutrition and its response to irrigation. In the

case/.....

case of irrigation we have a double effect in that an essential nutrient is added and also that the physical conditions of the soil are modified.

This investigation is aimed at an analysis of the root development as affected by the respective treatments and further to determine the inter-relations between root development and the development of the plant as a whole. The influence of the applications of Phosphate on the soil itself is to be investigated in order to determine in how far the fractions of phosphate in the soil have been affected. It is known that continued applications of Cations influence the soil to a marked degree and this aspect of the fertilization experiment has been fully investigated by Piaget.(15) It thus now remains to determine the role and influence of the anions on this soil, to complete the investigation.

A review of work on root development is given by Rogers (26) who himself adds a number of papers of fundamental importance, to the year 1939. He makes no mention of correlation between root development and fertilization practice studies as regards deciduous fruit trees nor can any reports of work of this nature be found in subsequent publications. The degree of root response to other factors has been widely studied and references are made to these studies in order to clarify some of the points raised in Chapter III. With regard to the Phosphate studies a considerable amount of work has been done. It still remains however, to be established which of the many fractions of soil Phosphate extracted can best be used as a criterion of soil fertility where deciduous fruit crops are concerned.

CHAPTER II.

DESCRIPTION OF THE EXPERIMENTAL BLOCKS AND METHODS OF INVESTIGATION.

The Bien Donne vineyard fertilization experiment consists of two experiments B and C as illustrated in figs. I and II. For the purpose of this investigation the experiments B and C will be termed "Blocks" B and C and their subdivisions referred to as 'sub-blocks' I, II, III etc. Statistically this is not the correct notation, but for clarity and convenience it is used in this discussion.

Block B. (Irrigated).

This block is 2.304 morgen in extent, measuring 360' x 576' and is divided into six sub-blocks of equal size, each consisting of twelve plots. Thus the block has 72 plots each 2160 sq. feet in size.

The rows of vines stand 10' apart and run the length of the block. The vines are Waltham Cross and Barlinka, three rows of each alternating. Each plot has six rows and extends 36' in length being isolated from the next plot in the row by an open strip 12' wide along which a subsoiler can be drawn to cut off any crossing roots. On each plot the perimeter vines are side vines and thus of the 36 on each plot 16 are experimental, eight of each type, four in a row.

There are twelve fertilization treatments on this block each being repeated once on every sub-block that is six repetitions. The figure (1) shows the distribution of the treatments the symbols being as follows:-

N_1 = 100 lbs $(NH_4)_2SO_4$ per morgen.

N_2 = 400 lbs " " "

N_3 = 800 lbs " " "

P_2 = 600 lbs 19% Superphosphate per morgen

K_2 = 600 lbs K_2SO_4 per morgen.

Block C/.....

FIGURE 1.

BLOCK B.

Sub-block							Sub-block
VI	F_1 N_2P_2	E_1 N_2	D_1 N_1K_2	C_1 N_2K_2	B_1 $N_1P_2K_2$	A_1 N_1	I
	F_2 N_1P_2	E_2 N_3	D_2 N_3P_2	C_2 N_3	B_2 N_2P_2	A_2 N_1K_2	
	F_3 $N_3P_2K_2$	E_3 $N_1P_2K_2$	D_3 N_3K_2	C_3 N_3K_2	B_3 $N_3P_2K_2$	A_3 N_2	
	F_4 N_2K_2	E_4 $N_2P_2K_2$	D_4 N_1	C_4 $N_2P_2K_2$	B_4 N_3P_2	A_4 N_1P_2	
V	F_5 N_1P_2	E_5 $N_1P_2K_2$	D_5 N_3K_2	C_5 $N_2P_2K_2$	B_5 N_2K_2	A_5 N_1P_2	II
	F_6 N_3P_2	E_6 $N_2P_2K_2$	D_6 N_2P_2	C_6 N_2	B_6 N_3K_2	A_6 N_2P_2	
	F_7 N_2K_2	E_7 N_2	D_7 N_3	C_7 N_3P_2	B_7 N_1K_2	A_7 N_1	
	F_8 $N_3P_2K_2$	E_8 N_1K_2	D_8 N_1	C_8 N_3	B_8 $N_3P_2K_2$	A_8 $N_1P_2K_2$	
IV	F_9 N_1K_2	E_9 N_3P_2	D_9 $N_2P_2K_2$	C_9 $N_3P_2K_2$	B_9 $N_1P_2K_2$	A_9 N_2P_2	III
	F_{10} N_2	E_{10} $N_1P_2K_2$	D_{10} N_1	C_{10} N_1P_2	B_{10} N_1K_2	A_{10} N_2	
	F	E	D	C	B	A	

FIGURE 2.

BLOCK C.

Sub-block							Sub-block
IV	F_1 N_2P_2	E_1 N_1P_2	D_1 N_2	C_1 N_3K_2	B_1 $N_1P_2K_2$	A_1 N_1	I
	F_2 N_3	E_2 N_1K_2	D_2 N_3P_2	C_2 N_2P_2	B_2 N_1K_2	A_2 N_3P_2	
	F_3 N_1	E_3 $N_1P_2K_2$	D_3 $N_3P_2K_2$	C_3 N_2	B_3 $N_3P_2K_2$	A_3 N_3	
	F_4 N_3K_2	E_4 $N_2P_2K_2$	D_4 N_2K_2	C_4 N_1P_2	B_4 N_2K_2	A_4 $N_2P_2K_2$	
III	F_5 N_1P_2	E_5 N_3K_2	D_5 N_2P_2	C_5 N_2	B_5 N_1K_2	A_5 $N_1P_2K_2$	II
	F_6 N_1K_2	E_6 N_2K_2	D_6 N_3P_2	C_6 N_3K_2	B_6 N_1P_2	A_6 N_3	
	F_7 $N_3P_2K_2$	E_7 $N_1P_2K_2$	D_7 N_3	C_7 $N_2P_2K_2$	B_7 N_1	A_7 N_3P_2	
	F_8 $N_2P_2K_2$	E_8 N_1	D_8 N_2	C_8 N_2K_2	B_8 N_2P_2	A_8 $N_3P_2K_2$	

FIGURE 1.

BLOCK B.

Sub-block							Sub-block
VI	F_1 N_2P_2	E_1 N_2	D_1 N_1K_2	C_1 N_2K_2	B_1 $N_1P_2K_2$	A_1 N_1	I
	F_2 N_1P_2	E_2 N_3	D_2 N_3P_2	C_2 N_3	B_2 N_2P_2	A_2 N_1K_2	
	F_3 $N_3P_2K_2$	E_3 $N_1P_2K_2$	D_3 N_3K_2	C_3 N_3K_2	B_3 $N_3P_2K_2$	A_3 N_2	
	F_4 N_2K_2	E_4 $N_2P_2K_2$	D_4 N_1	C_4 $N_2P_2K_2$	B_4 N_3P_2	A_4 N_1P_2	
V	F_5 N_1P_2	E_5 $N_1P_2K_2$	D_5 N_3K_2	C_5 $N_2P_2K_2$	B_5 N_2K_2	A_5 N_1P_2	II
	F_6 N_3P_2	E_6 $N_2P_2K_2$	D_6 N_2P_2	C_6 N_2	B_6 N_3K_2	A_6 N_2P_2	
	F_7 N_2K_2	E_7 N_2	D_7 N_3	C_7 N_3P_2	B_7 N_1K_2	A_7 N_1	
	F_8 $N_3P_2K_2$	E_8 N_1K_2	D_8 N_1	C_8 N_3	B_8 $N_3P_2K_2$	A_8 $N_1P_2K_2$	
IV	F_9 N_1K_2	E_9 N_3P_2	D_9 $N_2P_2K_2$	C_9 $N_3P_2K_2$	B_9 $N_1P_2K_2$	A_9 N_2P_2	III
	F_{10} N_2	E_{10} $N_1P_2K_2$	D_{10} N_1	C_{10} N_1P_2	B_{10} N_1K_2	A_{10} N_2	
	F_{11} N_3K_2	E_{11} N_1P_2	D_{11} N_2P_2	C_{11} N_3P_2	B_{11} N_1	A_{11} N_3	
	F_{12} N_3	E_{12} $N_3P_2K_2$	D_{12} N_2K_2	C_{12} N_2K_2	B_{12} $N_2P_2K_2$	A_{12} N_3K_2	

TABLE 1.

AVERAGE RESULTS OF MECHANICAL ANALYSIS FOR N_1 AND N_3 PLOTS OF BLOCK B AND C.

BLOCK	DEPTH	VERY FINE SAND		FINE SAND		COURSE SAND		TOTAL COLLOID		CLAY		SILT.	
		N_1	N_3	N_1	N_3	N_1	N_3	N_1	N_3	N_1	N_3	N_1	N_3
	0-6"	4.9	4.5	74.6	75.1	2.1	3.6	11.7	12.4	8.2	10.6	7.2	6.2
B	6"-12"	6.3	3.2	63.4	79.7	2.5	2.0	19.2	12.0	14.0	9.5	13.8	5.6
	12"-24"	3.2	3.0	70.9	76.5	3.8	3.5	14.5	13.1	10.2	12.4	8.4	9.0
	0-6"	4.0	5.1	75.2	69.0	2.0	2.6	14.1	15.8	7.5	11.2	13.6	12.1
C	6"-12"	5.6	5.4	73.6	74.0	2.3	2.8	13.3	13.3	11.5	10.0	12.2	7.8
	12"-24"	5.1	4.3	76.4	75.2	3.5	3.2	14.8	14.2	9.8	9.4	13.0	11.2

Block C. (dry land)

This block is 1.576 morgen in size and has exactly the same layout as that of Block B except that here there are only four sub-blocks instead of six (Fig 2).

General:-

During the first four years a cereal crop was planted during the winter as a green manure but as it reacted to the fertilisers to a marked degree this was discontinued.

From the beginning Block B has been irrigated in summer so that the moisture content never drops below 1.7% above wilting point, whereas Block C is left dry. In practice this implies 2 - 3 irrigations per season. Ploughing is done to a depth of 6" with a disc plough and so the top 9" can be considered disturbed soil.

The soil of these two blocks is alluvial sand deposited by the Bergriver. In general it can be described as a sandy silt with small variations in different areas. A mechanical analysis gives the results shown on Table I.

Until 1946 the practice was to prune the vines and allow them to bear according to their individual growth. As this implies the introduction of a further variation not allowed for in the statistical lay-out, the first crop results are of little value. This process was then discontinued and standard pruning procedure adopted for all the vines, irrespective of their growth and condition. From this time on the fertilization differences began to show up.

Methods of Investigation.

(1) Root Survey.

In order to study the development of the rooting system of the vines observation trenches were made on all the N_1; N_1P; N_1K; N_1PK; N_3; N_3P; N_3K; and N_3PK plots. In each case the centre vines were taken and only the Barlinka vines were investigated. The reason for this is as

follows:/.....

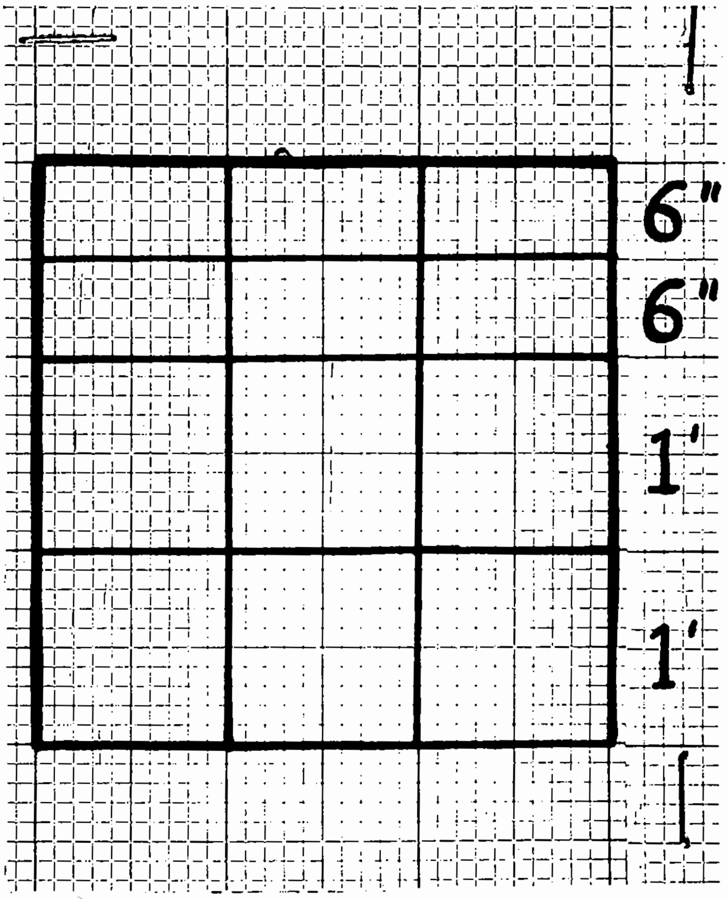
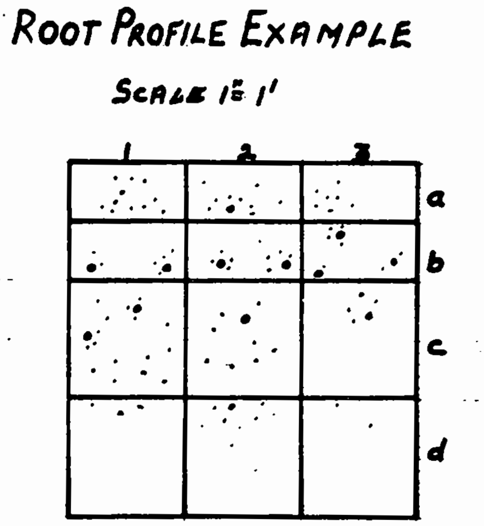


FIGURE 3. Root Sampling Frame.



1a = 3·3 gm	1c = 27·8 gm
2a = 4·7 "	2c = 17·5 "
3a = 4·8 "	3c = 7·1 "
1b = 13·9 "	1d = 6·0"
2b = 16·8 "	2d = 15·8"
3b = 21·6 "	3d = 3·8"

FIGURE 4. Root Profile Example.

follows: The crop records show that the Waltham Cross has, in the last few years, deteriorated rapidly as a result of the unbalanced fertilization. At the time of the investigation many of the vines were already dead and the overall condition was very poor. The Barlinka shows a similar decline but is apparently more hardy and does not show the same degree of decline. Thus in the case of Waltham Cross they are almost all uniformly bad, while the Barlinka, though declining, still show up fertilisation differences.

The observation trenches were dug 30" from the stem of the vine extending 3' on either side of the vine and to a depth of a little more than 3'. A frame measuring 3' x 3', and sub-divided into 12 blocks was then used to divide up the face of the trench, the top three being 6" high and 1 foot long, followed by a similar three followed by three blocks 1' x 1' followed by another three 1' x 1'. See fig. 3. The frame is held against the face of the trench so that its centre coincides exactly with the stem of the vine where the latter leaves the ground. These blocks were then cut out to a depth of 6" into the wall, each block carefully sieved and all the roots sorted out from the soil. After the roots had been washed they were separated into two groups, those above ⅛" - and those below ⅛" in diameter oven dried at 60°C and then weighed. At the same time a count was made of the roots at the root face and each block scored according to the degree of root distribution.

Figure 4 gives an example of a root profile together with the root weights.

<u>Analytical Methods:</u>

For the soil analysis, samples were taken on the same plots as for the root survey; that is on all except the N_2 plots. Samples were taken from four places around the centre of each plot and composite samples made of each of the following depths.

0" - 9"	15" - 18"
9" - 12"	18" - 24"
12" - 15"	24" - 36"

One of the aims of the investigation is to determine the movement, if any, of the Phosphate in the soil, hence the practice of using the top 9" of disturbed soil as the first sample followed by relatively shallow layers of 3" each.

On these samples Nitrogen was determined according to the Kjeldahl (1) method using Boric acid to neutralise the distilled ammonia.

The pH was read on the Beckman pH meter, using a glass-electrode-calomel electrode system. 50 gms. of soil in 50 ml. of water was used.

Phosphate was determined in three fractions:-

(a) 1% Citric acid soluble fraction (3) was extracted and determined colorometrically with Ammonium Molybdate and 1,2,4, Amino naphthol Sulphonic acid (3).

(b) Ammonium Fluoride soluble fraction was determined according to a modified method based on that proposed by Bray(4)

Modified Method.

Reagents:-

(1) 55.5 gms. NH_4F in 1500 ml.. water.

(2) 2N-HCl

(3) Sugar charcoal (tested P free)

(4) Extracting solution

30 ml. of (1)

12½ ml. of (2)

made to 1 liter

(5) Saturated H_3BO_3 - solution

(6) 124 amino-nophthol-sulphonic acid reagent.

(7) Ammonium molybdate in HCl.

Method:/....

Method:

20 gms of soil plus 200 ml. of extracting solution (4) put into an end over end shaking machine for 30 minutes. This is filtered through a Whatman No. 12 fluted filterpaper. A 50 ml. aliquot of the filtrate is added to 2 gms. of charcoal (3) and filtered through Whatman No. 40 filter paper. The clear colourless filtrate is then used for the determination. An aliquot containing 10 to 120 micrograms of Phosphate is pippetted into a 50 ml. measuring flask. Add 1 ml. conc. HCl, 10 ml. saturated H_3BO_3 and make up to ± 45 ml. Add 1 ml. Ammonium Molybdate (7) and 1 ml. ANS (6). Wait 15 minutes, and read on Evelyn photometer. A standard solution giving a reading of 50 on the Galvenometer is used to set the instrument.

(c) Conc HCl extract for total P according to the method described by Piper[1]

Statistical Methods:-

Blocks B and C are randomised blocks with a factorial design and the results obtained can thus be interpreted statistically according to the example shown on table (5). The significance of the F is then obtained from the tables published in the Bulletin of Drs. Saunders and Rayner (5).

In order to check the analytical work a number of extra samples taken from the plots were very well mixed to give a uniform compound sample.

For every group of twelve soils a sample of this soil was included and subjected to exactly the same treatment as is received by the other samples. When all the work was completed the results obtained by the repeated analysis of this soil were collected and the percentage deviation determined for each determination. The values obtained are given in tables (2) and (3). In all cases the percentage deviation is well below 5% and thus the work can be considered satisfactory.

TABLE (2)

% DEVIATION FOR CITRIC ACID EXTRACTION OF SOIL PHOSPHATE.

% PHOSPHATE FOUND IN REPEATED EXTRACTIONS OF THE SAME SOIL.

	%P	DEV.		$DEV.^2$	
	.00240	4		16	
	240	4		16	
	220	-16		256	
	223	-13		169	
	237	1		1	57.29 = 7.57
	240	4		16	
	230	-6		36	% Dev. = $\frac{7.57}{236}$x100
	247	11		121	
	227	-9		81	= 3.20%
	240	4		16	
	227	-9		81	
	233	-3		9	
	240	4		16	
	240	4		16	
	240	4		16	
	240	4		16	
	240	4		16	
	237	1		1	
	240	4		16	
	240	4		16	
	240	4		16	
	220	-16		256	
22	5181		21	1203	
	236			57.29	

% DEVIATION FOR NH_4F EXTRACTION OF SOIL PHOSPHATE.

% PHOSPHATE FOUND IN REPEATED EXTRACTIONS OF THE SAME SOIL.

%P	Deviation	$Dev.^2$
.00370	-30	900
.00360	-40	1600
390	-10	100
410	10	100
420	20	400
390	-10	100
420	20	400
380	-20	400
390	-10	100
380	-20	400
400	-20	-
380	-20	400
380	-10	400
390	10	100
410	-20	100
380	-10	400
390	-	100
400	10	-
410	30	100
430	40	900
440	-	1600
400	-10	100
390	-10	-
390		100
		23/8800
24 /9600		3826
400		

% Deviation = 4.89%

CHAPTER II.

THE RESPONSE OF VINE ROOTS TO FERTILIZATION.

INTRODUCTION.

There is no easy method of studying root systems states Weaver[6] and this very apt statement perhaps accounts for the relative lack of research on this aspect of plant growth. Where the root systems of tree crops are to be studied there are only two methods that can be employed. Glass-walled boxes or pits being the first, and observation trenches the second. In the latter case the study cannot follow development, but must be used to show the differences in the accumulative effect of such factors of importance as soil types, cultural practices and fertilization. This is the method adopted in this survey.

The study of root development on the Bien Donne Vineyard fertilization experiment was conducted on the Barlinka vines only.

The root stock used for the Barlinka is Jacques. H.S. le Roux observes, in his unpublished thesis[7] in which he compares the rooting systems of different root stocks, that the Jacques has a comparatively wellbalanced root system. It is always dominated by one large, heavy root, but the distribution of smaller roots is balanced. Further he observes that the system shows a tendency to be shallow, although under favourable conditions, roots will penetrate to a good depth.

The ideal method of root survey would be to remove the vine entirely from the soil and weigh off the total root weight; however this could only be done if the experiment were to be scrapped and the vines no longer required, but where the plants are to remain the only way is to remove a portion of the roots and use this as an index of root development. Hence the procedure as described under 'Methods of Investigation' Chapter I. Before this method was adopted

certain/....

certain of the plots were sampled on both sides of the vines in order to test the reliability of the index. In the rows of vines running North-South, observation trenches were made on both the East and West sides of the vine and samples taken as described. The results as shown on Table (4), indicate that over a large number of repetitions the error is not great and thus the author felt justified in continuing the investigation with trenches on the West side only.

It will be appreciated that on individual plots factors such as height of water table, or differences in the soil structure will affect the root development materially. These differences however are localised and not of such importance that they can have a great effect when incorporated with the repetition of similar treatments. This, as will be seen, is borne out by the results where the total root weights show no significant differences from the respective sub-blocks.

BLOCK C. (dry land).

Total Root Weights.

Table (5) shows that a statistical interpretation of the total root weights of all the plots investigated on Block C, reveals a significant difference in the weights derived from the different treatments; and that this difference is significant at the 5% level. Further, there are no significant differences between the weights obtained from the four sub-blocks.

A detailed investigation of the effect of the fertilizers shows that Phosphate has the most important influence. It causes weight differences that are significant at the 1% level and also shows a significant interaction with Nitrogen, the latter at the 5% level. In other words although the soil is uniform to a degree where it does not interfere with the general development of roots there are none the less differences in the weights obtained from plots. These differences are due to the fact that fertilization on the plots varies, Phosphate

being/.....

TABLE 4.

ROOT WEIGHTS (in gms.)

BLOCK C.

	East of N_1K Plots.				West of N_1K Plots.			
Plot	Top ft.	2nd ft.	3rd ft.	Total	Top ft.	2nd ft.	3rd ft.	Total
B_2	15.40	31.90	5.20	52.50	24.70	28.80	4.70	58.20
B_5	13.90	58.95	10.40	83.25	44,90	103.90	15.70	164.50
E_2	19.80	33.90	13.15	66.85	16.30	37.10	8.40	61.80
F_6	13.20	109.30	37.90	160.40	27.60	75.40	10.20	113.20
Total	62.3	234.05	66.65	363.00	113.5	245.20	39.00	397.70
Average	15.58	58.51	16.66	90.75	28.40	61.30	9.75	99.43

	East of N_3K Plots.				West of N_3K Plots.			
Plot	Top ft.	2nd ft.	3rd ft.	Total	Top ft.	2nd ft.	3rd ft.	Total
F_4	42.40	119.90	16.80	119.1	16.30	72.70	11.90	100.90
E_5	12.10	53.20	19.30	84.6	3.30	54.90	25.60	83.80
C_1	19.50	27.00	11.30	57.8	27.60	31.40	5.40	64.40
C_6	9.80	26.70	10.30	46.8	8.20	75.10	13.70	97.00
Total	83.80	226.80	57.70	368.30	55.40	234.10	56.60	346.10
Average	20.95	56.70	14.43	92.08	13.85	58.52	14.15	86.52

TABLE 5.

TOTAL ROOT WEIGHTS IN GMS. PER PLOT

BLOCK C.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK
Block I	70.90	143.80	66.50	175.40	58.20	64.40	61.70
II	207.60	24.60	116.90	196.10	164.50	97.00	130.30
III	80.80	72.70	210.80	141.10	61.80	100.90	145.10
IV	52.00	130.70	87.50	149.10	113.20	83.80	74.60
Total	411.30	371.80	481.70	661.70	397.70	346.10	411.70

	N_3PK	Total
Block I	152.70	793.60
II	259.60	1196.60
III	228.20	1041.40
IV	134.80	825.70
Total	775.30	3857.30

Sum of squares for all plots = 568750.19

Correction factor ($\frac{GT^2}{n}$) = 464961.30

Remainder: Sum of squared deviation for all plots = 103788.89 (a)

Sum of squares of treatments total = 2025822.19

÷ 4 = 506455.55

(Subtract Correction Factor)

Remainder = 41494.25 (b)

Sum of squares of block totals 3827946.97

÷ 8 478493.38

Remainder = 13532.08 (c)

Sum of squared deviation due to error (a-(b+c)) = 48762.56

Table 5 (Cont.)

Comp.	DF.	S.S.	M.S.	F.
Blocks	3	13532.08	4510.69	1.94
Treatments	7	41494.25	5927.75	2.55*
Error	21	48762.56	2322.03	
Total	31			

NP

	N	N_3	Total
-P	809.00	717.90	1526.90
+P	893.40	1437.00	2330.40
Total	1702.40	2154.90	3857.30

			M.S.	F.
S.S. for body of table	(÷ 8 (Subt. C.F.)) =		39162.95 (a)	
S.S. " N.	(÷ 16(")) =		6398.68 (b)	2.76
S.S. " P.	(÷ 16	=	20175.43 (c)	8.62 **
S.S. " NP.	(a-(b+c)		12588.84	5.42 *

NK.

	N_1	N_3	Total.
-K	893.00	1033.5	1926.50
+K	809.40	1121.4	1930.80
Total	1702.40	2154.9	3857.30

		M.S.	F.
S.S. for body of table	(÷ 8 (Subt. CF))=	7318.4 (a)	
S.S. for N	(÷16 ")=	6398.68(b)	2.70
S.S. for K	(÷16 ("))=	169.3 (c)	1
S.S. for NK	a-(b+c)	744.7	1

PK.

	-P	+P	Total
-K	783.10	1143.40	1926.50
+K	743.80	1187.00	1930.80
Total	1526.90	2330.40	3857.3

			M.S.	F
S.S. for body of table	(÷ 8 (Subt. C.F.))	=	20294.0(a)	
S.S. for P	(÷ 16 "	=	20175.4(b)	8.62**
S.S. for K	(÷ 16 "	=	169.30(c)	1
S.S. for PK.	a-(b+c)	=		1

being the most important nutrient. Further, the chances that these differences are accidental are one in twenty and where Phosphate is concerned, one in a hundred.

The statistical interpretation, while showing clearly which differences can be considered valid indications of plant reaction do not always give the entire picture. Figure (5) gives a graphic representation of the total root weights on the different treatments. The variations indicated by the statistics are illustrated and it is now clear that applications of Phosphate increase the root development. Where Nitrogen is added the root development is boosted still further. Nitrogen alone has no influence.

For all practical purposes N_1 can be considered as no Nitrogen.

Potash also has no effect on the root development. N_1 and N_1K as well as N_3 and N_3K have almost the same weights although N_3PK does show an increase of 7% over N_3P. This latter is, however, rather an illustration of the desirable effect of balanced fertilization than the effect of individual action or reaction.

Consider now the case of the N_1PK treatments. Here the weight of the roots is the same as that on the N_1 plots and yet phosphate which has a significant stimulating influence on root development is present. That deterioration has occurred is obvious from the fact that there is a weaker root system than is present on the N_1P plots. This deterioration can only be ascribed to the fact that disproportionally large doses of phosphate and potash were given in the absence of Nitrogen. In the beginning natural reserves of nitrogen boosted growth on the N_1PK plots, but when these were exhausted the plants deteriorated. The N_1 plots on the other hand have been able to maintain a steady low rate of growth as the balance of nutrients has not been radically disturbed.

It will now be of interest to determine whether these influences are on the entire root system or whether they are more/......

more pronounced on fine roots than on thick roots or if other factors come into play.

TABLE 6.

Total weight of Roots of diameter less than ½" (gms.)

Block C.

	N_1	N_3	N_1P	N_3P	N_1k	N_3K	N_1PK	N_3PK	Block Total
Block I	70.9	107.9	66.5	86.6	30.2	64.4	44.2	148.0	618.7
II	80.1	24.6	60.9	90.2	68.2	39.8	68.7	73.7	506.2
III	59.2	72.7	141.2	141.1	38.3	43.9	67.4	163.3	727.1
IV	52.0	95.6	75.1	102.3	70.5	74.3	44.7	85.2	599.7
Treatments Totals	262.2	300.8	343.7	420.2	207.2	222.4	225.0	470.2	2451.7 F

Camp	D.F.	S.S.	M.S.	F.
Block	3	3079.12	1026.37	1.33 N.S.
Treatment	7	16669.75	2381.39	3.10*
Error	21	16110.03	767.14	
Total	31			

NP.

	N_1	N_3	Total.
-P	469.4	523.2	992.6
+P	568.7	890.4	1459.1
	1038.1	1413.6	2451.7

NK.

	N_1	N_3	Total
-K	605.9	721.0	1326.9
+K	432.2	692.6	1124.8
Total	1038.1	1413.6	2451.7

PK.

	-P	+P	Total
-K	563.0	763.9	1326.9
+K	429.6	695.2	1124.8
Total	992.6	1459.1	2451.7

F for N = 7.04* F for NP = N.S.
F for P = 10.17** F for NK = N.S.
F for K = 1.66 F for PK = N.S.

TABLE 7.

Roots of diameter more than $\frac{1}{4}$". (gms.)

Block C.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Block Totals
Block I	-	35.9	-	88.8	27.4	-	17.5	4.7	174.3
II	74.5	-	56.0	105.9	96.3	57.2	61.6	185.8	637.3
III	21.6	-	58.6	-	23.5	57.0	77.7	64.9	303.3
IV	-	35.1	12.4	46.8	42.7	9.5	29.9	49.6	226.0
Treatment Totals	96.1	71.0	127.0	241.5	189.9	123.7	186.7	305.0	1340.9

Camp	D.F.	S.S.	M.S.	F.
Block	3	16261.93	5420.64	7.9** *
Treatment	7	10805.36	1543.62	2.2 N.S.
Error	21	14302.39	681.06	
Totals n	31			

Table (6) which gives the total weights of roots less than $\frac{1}{3}$" in diameter and the statistical interpretation of these weights indicates similar trends as is the case of total root weights. As in the previous case the weights very significantly at the 5% level and Phosphate has a significant influence at the 1% level but in both cases the factor F is considerably higher. In this case Nitrogen has a significant influence at the 5% level and there is no interaction between Nitrogen and phosphate and no direct effect from Potash.

Fig. (6) gives a graphical representation of the weights and this would seem to indicate that Potash has a depressing effect on the root systems. N_1K and N_3K as well as N_1PK have a smaller weight of roots than does N_1. The stimulating effect

of/......

FIGURE 5.

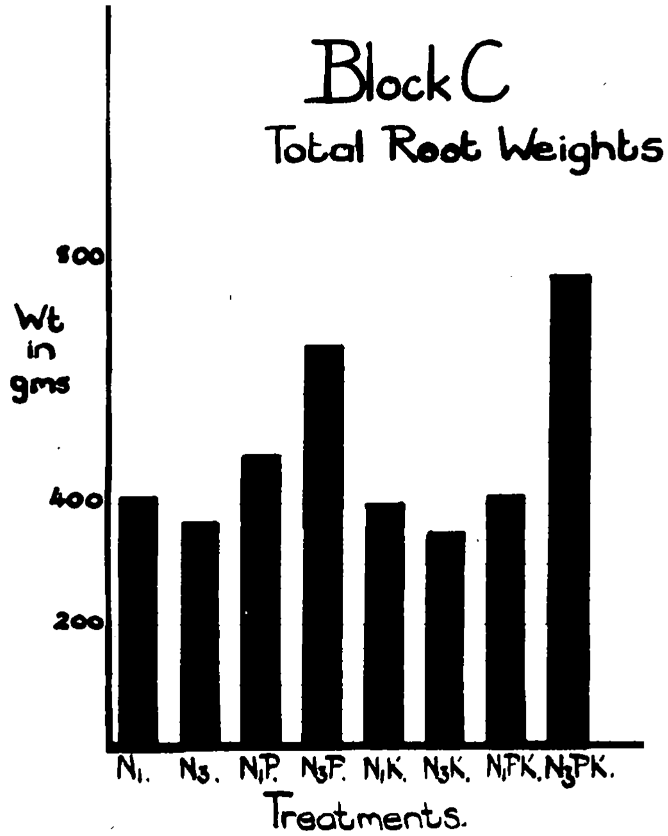
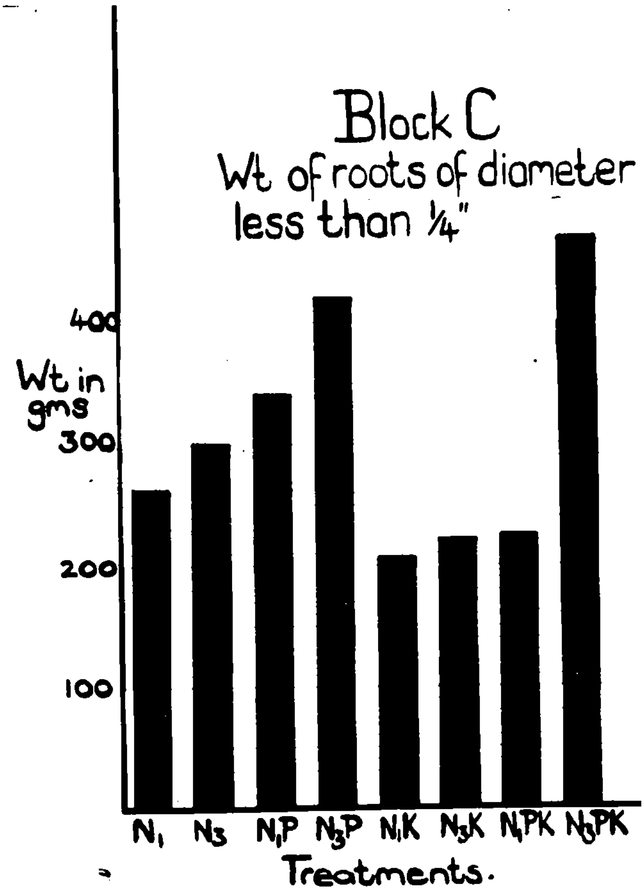


FIGURE 6.



of the Nitrogen and Phosphate fertilisation can be clearly seen.

Total weight of roots of diameter more than ½".

In the case of this larger type of root there is a pronounced difference in the weight of roots from the respective sub-blocks. This difference is significant at the 1% level (Table 7) and for this reason one can expect that the fertilisation effects will be overshadowed. This is the case and although the factor is reasonably large (the significant level is 2.49) no definite influences can be seen.

A graphical representation of the weights (Fig. 7) however brings to light a very important point. The weight of large roots on the N_1PK plots is only less than the $N_3'P$ and N_3PK plots. It is almost twice the weight of the N_1 plots. This is seen as proving that the N_1PK plots originally had a greater growth rate and that this has now deteriorated to a degree where it is less than that of the N_1 plots. (In van Niekerks' (8) proposed D.Sc. thesis the crop figures show an initial high production which has gradually decreased)

The smaller roots of a system are those which have been produced as a result of recent growth, if not largely the product of one season's growth. The larger roots are those which have been developed over a number of seasons and thus necessarily date from an earlier period in the plants growth.

Thus the large weight of heavy roots on the N_1PK plots, relative to the N_1, show a growth rate which was at one time far superior to that of the N_1 plots, but the poor development of smaller roots shows that this rate has deteriorated to such a degree that it is now less than that of the N_1 plots. On the N_3PK plots 35% of the roots by weight are of a diameter greater than ½". On the N_1 plots 30% are like this while on the N_1PK plots 50% of the roots are large.

It is of importance that tree crops have a deep root system in order to be able to withstand periods of drought and obtain sufficient nutrients for the plant. If they are irri-

gated/

gated this factor is still of importance as the deeper the system the less irrigation is required and thus the lower the production costs. For this reason the effect of fertilization on the distribution of the root system is of practical interest and warrants further study.

Weight of roots in top 6" of soil.

Firstly the statistical interpretation. Here is indeed a very surprising result. Significant differences are found at the 5% level and further analysis shows that this is caused by the interaction of N and K as well as P and K, both being significant also at the 5% level. There is no significant difference due to individual action and further it is a fact that this interaction is negative. That is, in all cases where N and K are added, or P and K the root development is depressed. (Table 8).

Again, on turning to graphical representation of the figures (Fig. 8) the position becomes somewhat clearer. The N_1 plots give the highest concentration of roots in the top 6", followed closely by the N_3 plots. On all the other plots the weight of roots in this layer of soil is small. When these weights are expressed as percentages of the total root weights then even the seemingly high N_3PK is seen to be a very small fraction of the total distribution. (Fig. 9).

Proebsting, in an article in the Proceedings of the American Society of Horticultural Science (9) states that "there is some evidence that absorption (by the roots of fruit trees) may be negligible in this zone (surface soil) even where a high concentration of an element such as potassium has been built up over a number of years." He goes further to suggest that in some cases the lack of roots in the surface area could be due to high temperatures. Yet in this case there is a sandy soil, unirrigated, which becomes very hot in summer, not fertilised and yet there is a strong or relatively strong root development in the top 6" of soil. The high trellising does

serve/.....

FIGURE 7.

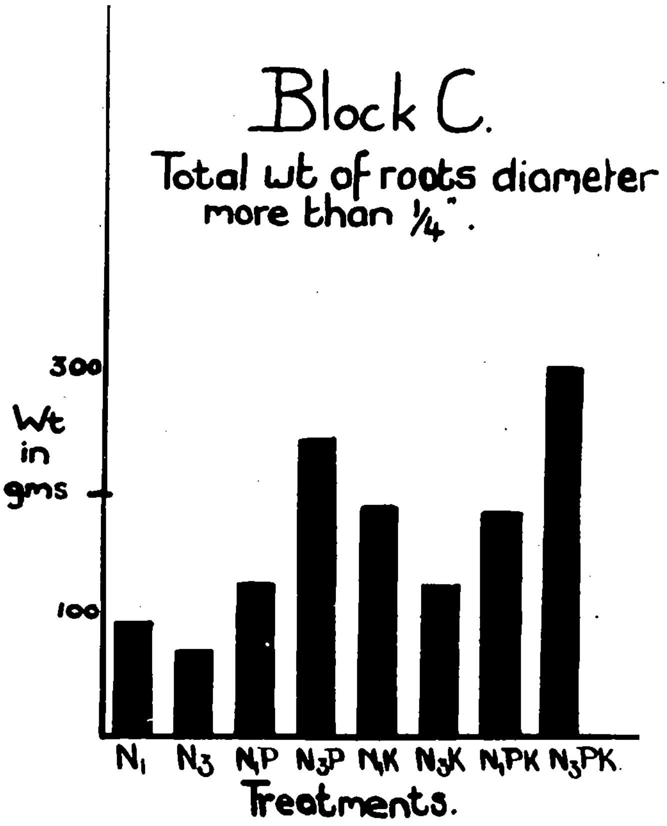


FIGURE 8.

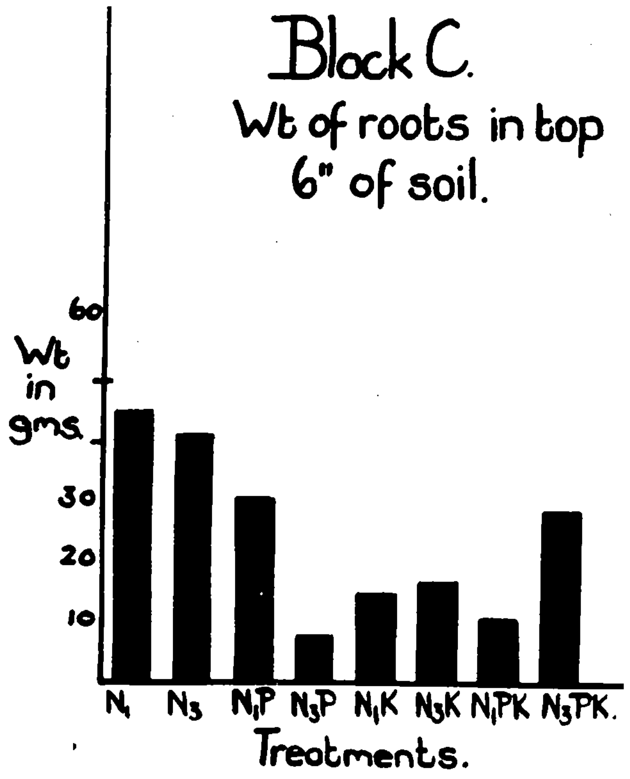


TABLE 8.

Weight of roots in top 6" of soil. (gms.)

Block C.

	N1	N3	N1P	N3P	N1K	N3K	N1PK	N3PK	Total
Block I	3.9	9.8	14.1	2.7	1.7	3.8	2.8	7.4	46.2
II	12.8	1.4	5.0	2.0	4.8	3.3	3.0	4.5	36.8
III	14.7	22.7	6.8	3.1	3.0	8.6	3.2	9.8	71.9
IV	15.2	7.1	4.6	0.9	6.0	1.1	2.2	7.7	44.8
Total	46.6	41.0	30.5	8.7	15.5	16.8	11.2	29.4	199.7

Comp.	D.F.	S.S.	M.S.	F.
Blocks	3	86.93	28.98	1·7 N.S.
Treatments	7	346.22	49.47	2.91*
Error	21	357.09	17.00	
	31			

N.P.

	N_1	N_3	Total
-P	62.1	57.8	119.9
+P	41.7	38.1	79.8
Total	103.8	95.9	199.7

NK.

	N_1	N_3	Total
-K	77.1	46.2	123.3
+K	26.7	49.7	76.4
	103.8	95.9	199.7

PK.

	-P	+P	Total
-K	87.6	39.2	126.8
+K	32.3	40.6	72.9
Total	119.9	79.8	199.7

F for N = Not significant
F for P = " "
F for NP = " "

F for K = Not significa[nt]
F for NK = 5.34*
F for PK = 7.20*

TABLE 9.

Weight of roots in second 6" of soil.

Block C.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Block Total
Block I	36.2	89.9	12.1	14.3	23.0	23.8	36.5	78.3	314.1
II	58.6	14.0	84.7	78.2	40.1	4.9	103.9	48.8	433.2
III	4.2	14.6	92.6	12.6	13.3	7.7	10.4	31.5	186.9
IV	3.8	4.6	15.3	1.6	21.6	2.2	1.1	12.7	62.9
Treatment Totals	102.8	123.1	104.7	106.7	98.0	38.6	151.9	1713	997.1

Comp.	D.F.	S.S.	M.S.	F.
Blocks	3	9582.12	3194.04	4.19[x]
Treatment	7	4560.91	651.56	<1
Error	21	16024.91	763.09	
Total	31			

FIGURE 9.

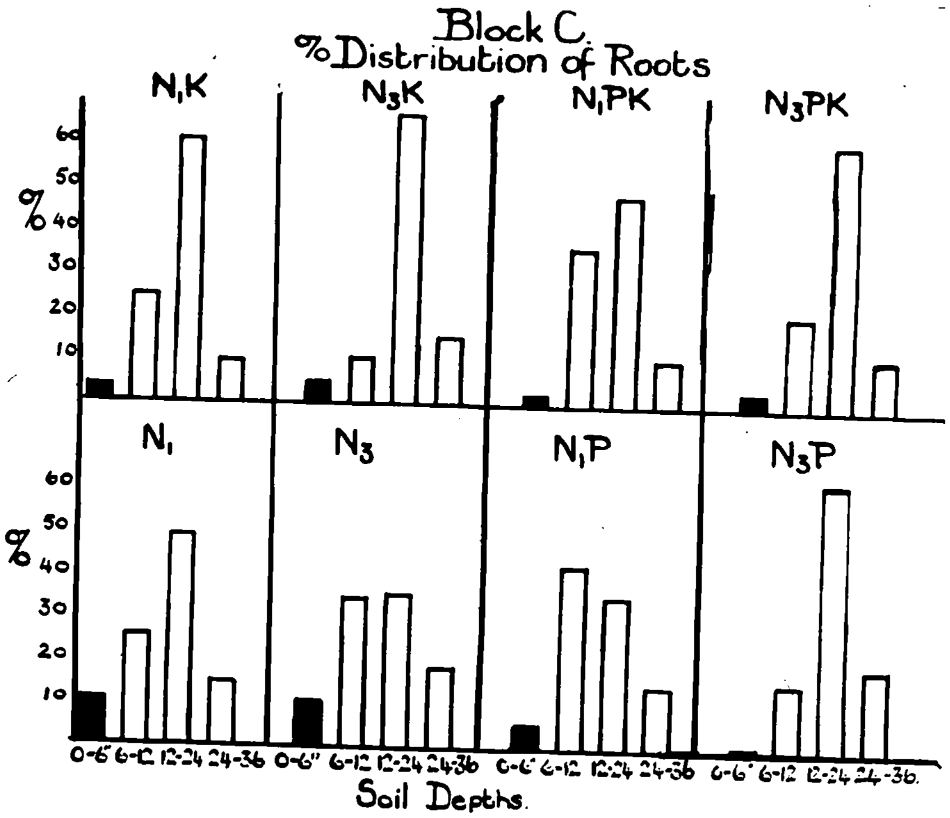

Block C.
% Distribution of Roots
N1K
N3K
N1PK
N3PK
N1
N3
N1P
N3P
%
60
50
40
30
20
10
0-6" 6-12 12-24 24-36
Soil Depths.

FIGURE 10.

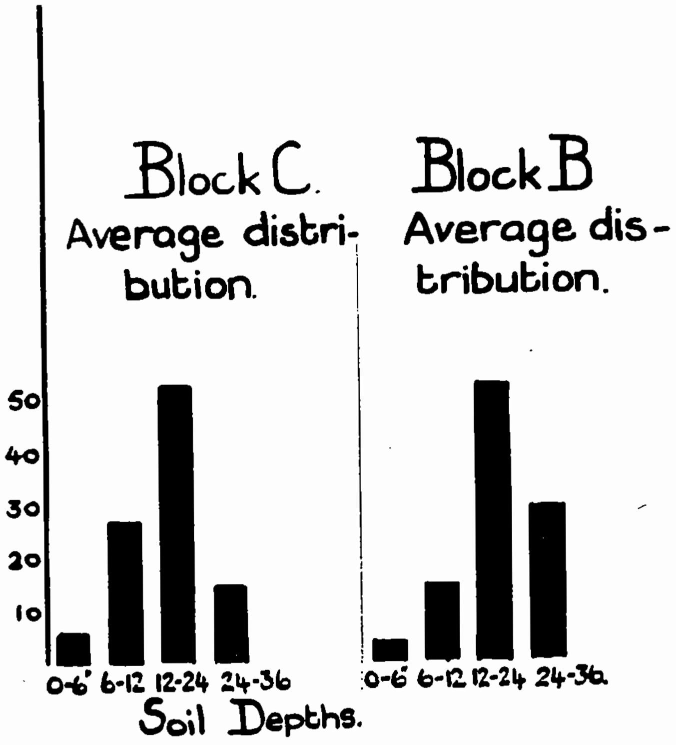
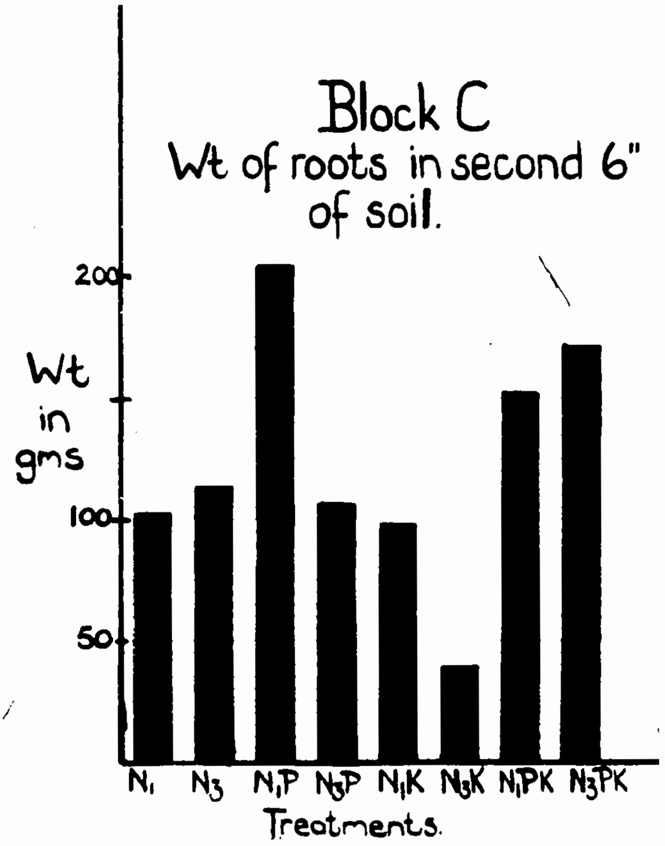


FIGURE 11.



[illegible] to [illegible] the soil but on [illegible] plot where the vegeta-tive growth of the vines [illegible] this does not help very much. The only explanation is that the roots, [illegible] used up the nutrients in the deeper soil, are now forced to exploit this less favourable zone in order to find the necessary nutrients. Where a high concentration of a nutrient is built up in the top soil a tendency must be noticed [illegible] into the lower layers. Here the concentration is low and no fertilization is applied, the possibility is strong that a certain amount of nutrients will remain in the top soil where the vine roots are forced to follow when the reserves in the lower soil start to drop. In a later chapter the plant nutrient content of the soil layers will be discussed and perhaps the results will bear out the above hypothesis.

All the roots in this zone have a diameter of less than 1 mm and can therefore be regarded as feeder roots.

<u>Weight of roots in the second ft. of soil.</u>

On an average 27% of the roots are in this soil layer (as shown in Fig. (10). Statistically the treatments totals show no variation but the sub-blocks differ significantly at the 5% level (Table 9). Approximately 60% by weight of the roots are greater than 1 mm in diameter. Fig. (11) which represents the weights of roots derived from the different treatments, shows that the greatest weight of roots comes from the N_1P plots, followed by the N_1PK and N_3PK. It thus appears that fertilizer still has an important influence on the root weights.

<u>Weight of roots in third foot of soil.</u>

In this layer an average of about 25% of the roots are found (Fig. 10) of which 5% by weight are more than 1 mm in diameter. Statistically the sub-blocks differ while the treatments differ considerably but not quite significantly (see Table 10). From the graph Fig. (12) we see that N_3P has the most weight, closely followed by [illegible] while [illegible]

[illegible]/.....

TABLE 10.

Weight of roots in second foot of soil.

Block C.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	20.1	34.4	29.6	141.70	28.8	31.4	18.7	56.6	361.3
II	110.6	4.2	17.8	64.50	103.9	75.1	16.7	191.5	584.3
III	50.0	18.3	76.1	83.6	37.1	72.7	114.3	142.6	594.7
IV	16.5	79.1	51.2	124.2	75.4	54.9	53.9	89.3	544.5
Total	197.2	136.1	114.7	414.0	245.2	234.1	203.6	480.0	2084.8

Comp.	D.F.	S.S.	M.S.	F.
Blocks	3	c4436.86	1478.95	<1
Treatments	7	b25701.78	3671.68	2.44 N.S.
Error	21	d31886.7	1518.41	
Total	31			

TABLE 11.

Weight of roots in third foot of soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	10.7	19.70	10.7	16.7	4.7	5.4	3.5	10.4	71.8
II	25.6	5.00	9.4	57.4	15.7	13.7	6.7	14.8	142.3
III	11.9	17.10	35.3	41.8	8.4	11.9	17.2	44.3	187.9
IV	16.5	39.9	16.4	22.4	10.2	25.6	17.4	25.1	173.5
Total	64.7	71.7	71.8	138.3	39.0	56.6	44.8	94.6	575.5

Comp.	D.F.	S.S.	M.S.	F.
Blocks	3	1001.64	333.90	3.20*
Treatment	7	1566.56	223.94	2.15 N.S.
Error	21	2189.20	104.25	
Total	31			

FIGURE 12.

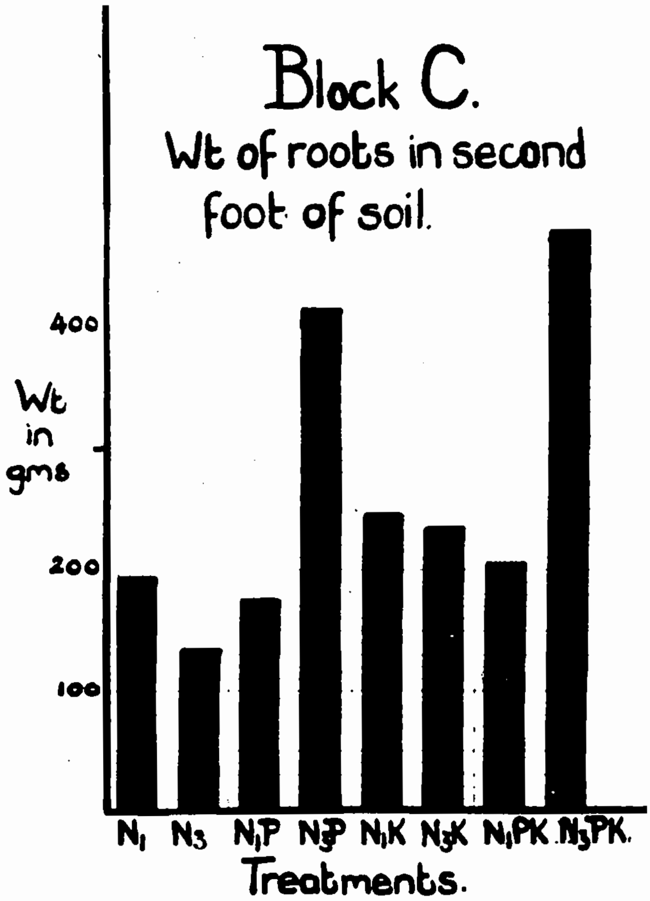
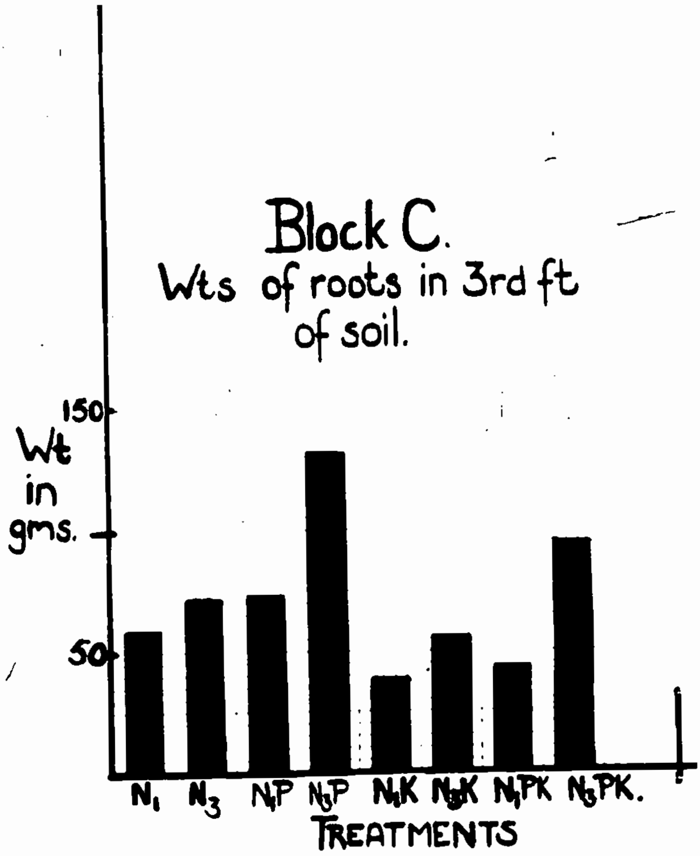


FIGURE 13.



falls far behind. As in die case of the second 6" P seems to have a pronounced effect but in one case the development is not what would be expected. This aspect of the distribution of the roots will again be discussed when the Phosphate content of the soil is examined in Chapters V, VI & VII.

Weight of Roots in 3rd foot of soil.

At this depth the water table exercises a significant influence and the weights of roots from the subblocks differ significantly at the 5% level See Table (11).

The treatment totals do not differ significantly but the graph shows that the N_3P and N_3PK plots have by far the greatest weight of roots. Only 3% of these roots are over $\frac{1}{8}$" in diameter and it is thus likely that in most cases the roots found here are seasonal and follow the water table in summer, only to die off again when inundated by the winter rains. The aspect is confirmed by Howard (10) 1940, in his book "An Agricultural Testament" pp. 120. He shows that decidious fruit roots extend their activity to the deeper soil layers during the dry season but retreat as the water table rises. Fig. 13 gives a graphical reproduction of the weights.

In general the profile studies indicate that the higher rate of Nitrogen plus Phosphatic fertilizer make for a deeper root system on the unirrigated C Block, as compared with the shallower system of the low nitrogen plus Phosphate fertilisation (Fig. 9) and the still shallower one of the non-fertilised N_1 plots.

Block B. (Irrigated).

On this area of the experiment the percentage moisture is not allowed to fall below 1.7% above the permanent wilting percentage. In practise this implies two or three

irrigations/....

irrigations per season. The area is flood irrigated in strips but the amount of water is not controlled. As a logical consequence of flood irrigation one expects a heavy leaching action on the soil and an uneven penetration. These two factors must both play an important part, as does the fact of irrigation itself, on the root development.

<u>Total Root Weights</u>.

To determine the effect of fertilisation the results were again tested statistically as shown on Table 12. In this case there are no significant differences whatsoever. Neither the fertilization nor the different sub-blocks show any variation.

The graphical representation of the weights Fig. 14, however, shows that they are not quite so devoid of any interest. Firstly the large weight of roots on N_3K attracts the attention. Secondly, but even more surprising, the relatively small weight of roots on the N_3PK plots.

It is now my intention to formulate a hypothesis and then attempt to prove it by means of the available results.

The hypothesis is as follows:-

A plant, growing under favourable conditions of moisture and nutrient supply, will produce a moderate root system. If any single factor is in short supply the plants will develop an extraordinarily large root system in order to obtain a sufficient amount of that single factor. The form taken by this larger root development will differ according to the nature of the deficient factor. For example a deficiency of water results in a large well-branched root system while lack of phosphate results in a more dense root system.

Before examining the proof of this hypothesis a brief review of the functions of the major nutrients, Nitrogen, Phosphate and Potash, together with that of water, would be of help. (11).

[illegible] 10.

[illegible]

[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] I	[illegible].70	91.60	74.20	15[illegible]	52.40	157.50	59.[illegible]	65.70
[illegible] II	241.30	75.50	114.30	1[illegible].40	135.70	167.[illegible]	126.70	142.[illegible]
III	56.35	131.40	66.50	102.60	59.15	176.60	62.[illegible]	113.[illegible]
IV	7.00	116.00	151.20	74.10	76.20	193.[illegible]	100.30	70.[illegible]
V	[illegible].10	214.00	23.10	22.20	141.90	233.60	1[illegible].10	1[illegible].9[illegible]
VI	87.60	19.50	23[illegible].75	172.[illegible]	127.80	95.60	259.5[illegible]	1[illegible].70
Total	7[illegible].03	6[illegible].00	6[illegible].50	6[illegible].30	[illegible].35	[illegible].30	7[illegible].00	7[illegible].20

	Total
[illegible] I	720.90
II	1213.90
III	790.60
IV	840.60
V	1216.50
VI	1175.00
Total	5963.70

[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	5	(a)	29[illegible]3.03	5826.61	1.1 N.S
[illegible]	7	(b)	14576.25	[illegible]082.32	<1
[illegible]	35	(c)	134623.90	[illegible]46.39	
Total	47				

(a) Water.

In addition to forming a part of the carbohydrates which the plant synthesises with the aid of chlorophyll and CO_2 gas of the air it acts as the medium of assimilation distribution in the plant, and transpiration.

(b) Nitrogen:

Is a constituent of all proteins and thus of all protoplasm.

(c) Phosphate:

A constituent of the cell nucleus, nucleo-proteins, and is essential for all cell division.

(d) Potassium:

Is not a constituent of any of the plant tissues but plays an important part in plant metabolism. It makes for more efficient utilisation of water and counterbalances the ill effects of an excess of Nitrogen.

In 1811 T.A. Knight (12) observed that roots will move towards moisture. That is to say, the plant is able, under dry conditions, to obtain moisture from moist soil layers at a considerable distance from the plant. It is also obvious that the more fertile the soil is with regard to nutrient elements the easier it will be for the plant to produce a large root system which will be able to obtain sufficient moisture during a relatively dry period. Rogers (29) in a root survey shows that the richer a soil the greater is the concentration of roots. A lack of nutrients will inhibit the growth and thus also render the plant less drought-resistant.

On the unirrigated block C (table 5) these facts are born out. The plots to which a full fertilization is added, N_3PK, have the largest root system. These plants, due to a sufficiency of the essential major mineral elements can best follow and utilise the small supply of water during the dry summer months. On all the other plots where one or more of

tho/.....

the elements N and K are lacking the root systems are smaller. The stimulating effect of phosphate, which has as yet not been explained, can perhaps to some degree, cloud the issue.

However, that it is moisture the plants are lacking for is illustrated by the fact that on the irrigated Block B, table (12) the N_3K plots have a very average root development. There is no great difference between its development and that of the N_1 or other plots. In fact, the only ones which do have larger systems are the N_3P plots, but these will be discussed later.

Now that it has been established that scarcity of water results in a large root system, provided N and K are present, taking into account also the stimulating effect of P, let us examine the effect of each of these nutrients singly in the presence of a sufficient supply of water and the other two elements.

As Block B is the irrigated area, our attention is concentrated on the results from this experiment.

Nitrogen:-

In the N_2PK plots (table 12) all elements are present except sufficient Nitrogen. The root system is a little bigger than that of the N_3PK plots, but not significantly so. If the hypothesis applied as stated above one would expect a large root system which would be developed in order to supplement the deficient Nitrogen. The only explanation for the absence of a large root system is that were it to develop one it would meet with little or no success as the natural reserves of N in these soils are low and rapidly exhausted. (Chapter VI)

Phosphate:-

The N_3P plots (table 12) show a far greater root development than any of the other plots. This is obviously not due to a stimulating effect of either of the elements individually or collectively as they are present on other plots,

singly/.....

singly and together, which do not have a large root system. The plot lacks only Phosphate, and Phosphate is present in the soil even if in low concentrations of a less available form. A large root system would be able to utilise a low concentration of the phosphate and the fact that both Nitrogen and K are present, ensures that it will be used to the best advantage.

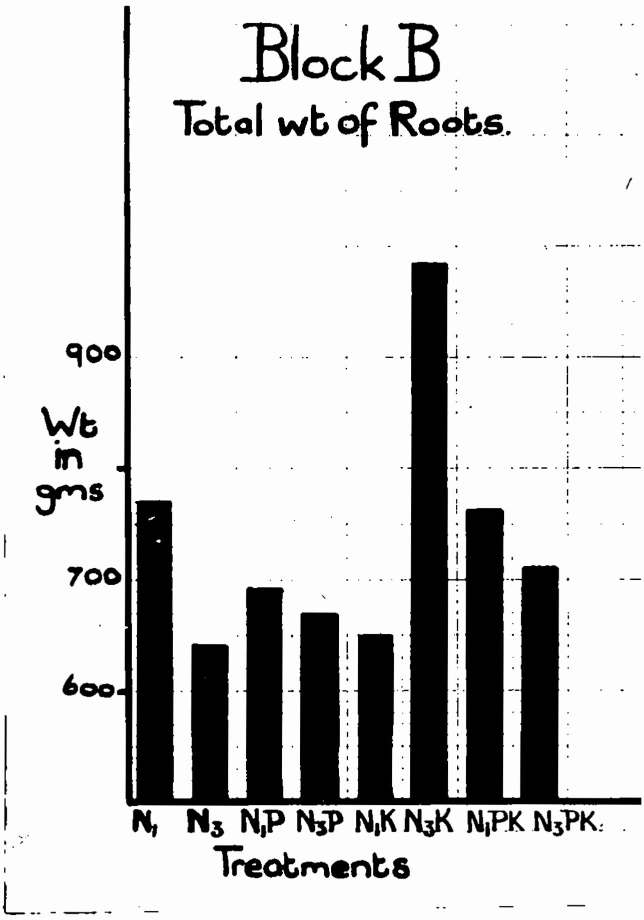
Potash:-

The N_3P plots (table 12) show a very average root development, and again the hypothesis does not hold good. The answer here is perhaps that due to an abundance of water and other nutrient elements the presence of Potash, which as we have seen, makes for more efficient utilisation of the other elements is not so essential. In other words the shortage is not so strongly impinged on the plant as to stimulate the production of a large root system in order to obtain the extra potash. Then there is also the consideration that both in the case of Nitrogen and Potash we have to do with a mobile element. That is, they will move through the soil in the soil moisture and thus the roots will be supplied from the entire root area. In the case of static phosphate on the other hand the plant can only feed in the root zone and thus must develop a large system in order to obtain the Phosphate.

The Hypothesis as previously formulated is thus too sweeping and will have to be re-stated as follows:- A plant growing under favourable conditions of moisture and nutrient supply will produce a moderate root system. Where there is a shortage of moisture the plant will compensate by producing a large root system. This is facilitated by a sufficient supply of Phosphate and will reach a maximum where all nutrients NPK are present. A shortage of Phosphate where the other three factors are favourable will also lead to an enlarged root system.

It/......

FIGURE 14.


Block B
Total wt of Roots.
900
Wt
in
gms
700
600
N1
N3
N1P
N3P
N1K
N3K
N1PK
N3PK
Treatments

It must be borne in mind that all the influences discussed above are secondary to Soil Structure and Texture.

Under conditions of unbalanced fertilisation plants are able, to a degree to compensate for the disbalance and obtain from what is usually regarded as negligibly or totally unavailable sources of Phosphate, a reasonable amount of this necessary nutrient. However this is only achieved at a price and the plant cannot obtain sufficient nutrient from these less advantageous forms and at the same time produce record crops. Nevertheless, this does perhaps account, to some degree for the fact that an addition of highly available superphosphate on the irrigated block only results in an 8% increase in crop, while Nitrogen and Potash cause as much as 30% increases (Mr. van Niekerk) (8) (See full description in Chapter IV).

It now remains to examine the two root fractions derived from Block B as well as the roots from the respective layers.

<u>Total Weight of Roots of diameter less than ¼".</u>

As is the case with the total root weights there are no statistically significant differences between the weights from the respective treatments. The N_3K plots however, also show a considerably greater weight of roots than any of the other plots (Table 13).

<u>Total Weight of Roots of Diameter more than ¼".</u>

As before there are no significant differences between the treatments. A point of interest, which will be discussed later, is the fact that there is also no significant difference between the weights derived from the sub-blocks. (Table 14) From table 13 and 14 it is seen that the large weight of roots from the N_3K plots, is due in main, to its greater weight of fine roots. The next greatest weight of fine roots is ± 25% less than that of N_3K while in the case of heavy roots the next greatest is only ± 15% less. This

would/.....

TABLE 13.

Weight of roots of diameter less than ½".

Block B.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	55.4	54.7	67.6	70.0	46.8	96.5	59.6	66.7	577.3
II	63.8	71.4	80.5	101.1	123.0	118.7	69.4	83.5	711.5
III	56.4	73.9	53.9	79.9	52.6	96.7	57.0	74.9	545.3
IV	60.1	51.0	61.5	67.5	36.8	57.7	48.2	61.1	443.9
V	148.8	121.5	11.7	17.0	94.8	146.3	90.3	53.4	683.8
VI	81.7	19.5	110.2	128.9	64.6	70.5	99.5	87.6	662.5
Total	466.2	392.0	385.4	464.4	418.6	586.4	424.0	427.2	3564.3

Comp.	D.F.	S.S.	M.S.	F.
Blocks	5	7168.44	1433.49	1.6 N.S
Treatment	7	4757.45	679.63	<1
Error	35	30772.03	879.20	
Totals	47			

TABLE 14.

Weight of roots of diameter more than ½".

Block B.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	25.3	26.9	5.8	68.2	15.6	61.0	-	-	202.8
II	77.5	4.1	34.3	59.3	62.7	48.3	57.3	59.0	402.5
III	-	57.5	32.6	22.7	2.6	79.9	5.6	43.9	244.8
IV	46.9	65.0	89.7	6.6	39.4	96.1	52.1	8.9	404.7
V	146.3	97.5	11.4	5.2	47.1	87.3	49.8	93.1	532.7
VI	5.9	-	128.5	43.9	62.6	25.3	166.0	81.1	513.3
Total	301.9	246.0	302.3	205.9	230.0	397.9	330.8	286.0	2300.8

Comp.	D.F.	S.S.	M.S.	F.
Blocks	5	11476.16	2295.23	<1
Treatment	7	4363.12	623.30	1.6 N.S.
Error	35	57232.87	1635.22	
Total	47			

TABLE 15.

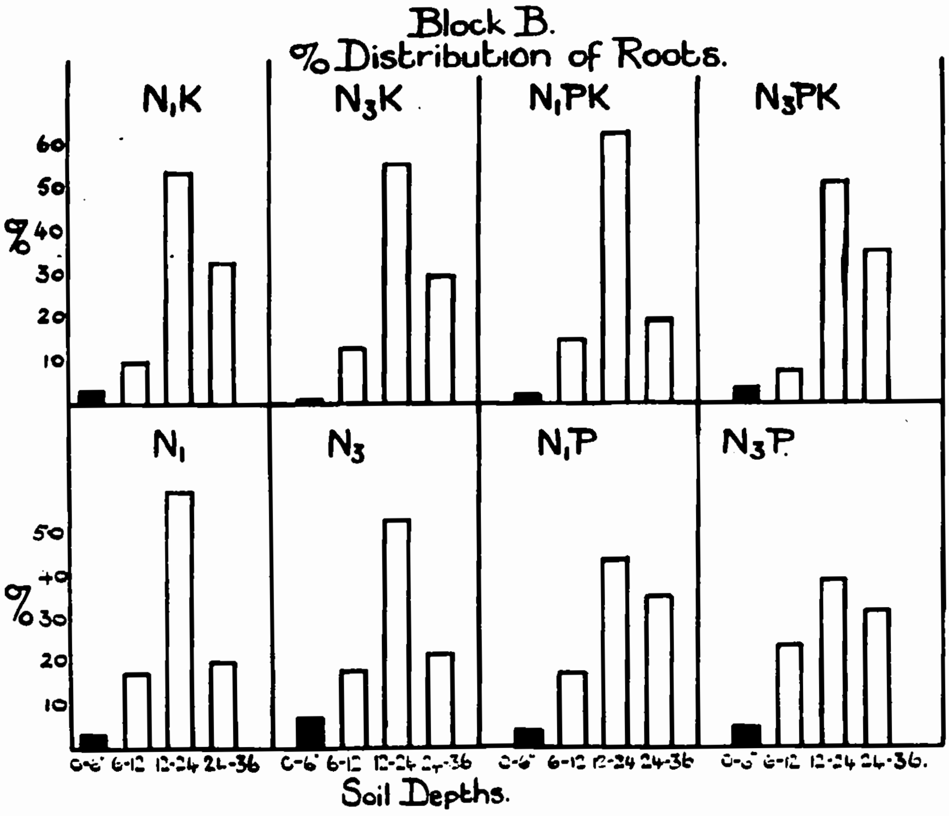
Weight of roots in top 6" of soil.

Block B.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	4.10	6.20	0.90	4.70	.70	3.00	4.30	4.50	28.4
II	8.60	8.10	2.50	10.50	1.90	3.80	4.80	4.80	45.6
III	.25	9.30	5.50	5.50	7.75	1.00	1.30	2.70	33.4
IV	2.60	4.20	15.50	5.80	0.40	0.30	4.80	4.00	37.6
V	2.80	8.60	2.00	0.90	2.90	1.70	0.00	1.40	20.3
VI	1.60	5.70	2.40	5.30	2.10	2.40	1.00	3.20	23.7
Total	19.95	42.70	28.80	32.70	15.75	12.20	16.20	20.60	189.0

Comp.	D.F.	S.S.	M.S.	F
Blocks	5	c 54.43	10.89	1·4 N.S.
Treatments	7	b 123.60	17.90	2.21 N.S.
Error	35	d 280.60	8.02	
	47			

FIGURE 15.


Block B.
% Distribution of Roots.
N1K
N3K
N1PK
N3PK
N1
N3
N1P
N3P
%
10
20
30
40
50
60
0-6" 6-12 12-24 24-36
Soil Depths.

would tend to indicate that an increase of the plants root feeding-zone is of greater importance than the increase of the root-feeding area. This points to the pursuit of an immobile nutrient (Phosphate) rather than any relatively mobile essential (Nitrogen, Potash and Water).

0"-6".

Table (15) indicates no significant differences between the treatments. It may be asked why there is not a similar effect here as is found on Block C, namely that no fertilization causes the roots to develope into the top 6" of soil, especially as this irrigated soil would be cooler. A possible reason, but one that cannot be stated definitely until the analytical data of the soil has been examined, (Chapter V and VI) is that the strong leaching action of the irrigation water washes whatever available nutrient there is in this upper layer down to the roots. The possibility is also there that the strong weed-growth in summer on this irrigated Block serves to convert what reserves there are into a mobile form which then moves more easily into the deeper soil. On all the treatments the percentage of roots in this layer is below 6% (Fig. 15).

6-12" (Table 16).

With the exception of a significant difference between the sub-blocks there are no differences due to the treatments nor are there any indications. With the exception of the N_3P plots (24%) the root concentration is below 20%.

12-24". (Table 17).

Table (17) shows that there are no differences either in the treatments or sub-blocks. This layer has the highest concentration of roots which is in all cases more than 50% of the total root weights. This latter with the exception of N_1P and N_3P plots on which 44% and 39% are found respectively. Fig. (15).

24 - 36"/....

TABLE 16.

Weight of roots in second 6" of soil.

Block B.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	26.9	17.8	30.2	85.5	11.3	8.5	28.5	11.5	220.2
II	54.2	7.2	45.4	11.1	18.3	33.9	59.6	21.4	251.1
III	19.4	75.4	5.1	42.8	19.5	70.5	9.0	4.1	245.8
IV	12.8	12.0	2.1	12.8	8.6	6.2	2.9	6.7	64.1
V	8.8	11.8	5.6	1.9	5.9	9.1	4.8	2.0	49.9
VI	6.7	0.8	36.2	8.7	4.5	4.2	5.5	17.0	83.6
Total	128.8	125.0	124.6	162.8	68.1	132.4	110.3	62.7	914.7

Comp.	D.F.	S.S.	M.S.	F.
Blocks	5	5762.33	1152.47	3.16*
Treatment	7	1320.62	188.66	<1
Error	35	12756.13	364.46	
Total	47			

TABLE 17.

Weight of roots in second foot of soil.

Block B.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK
Block I	45.30	53.60	39.10	36.20	44.60	91.50	15.70
II	60.80	48.60	58.30	29.70	137.10	87.80	59.60
III	27.40	37.40	61.60	31.40	16.50	92.10	40.10
IV	80.00	96.70	00.90	50.20	61.60	78.50	83.60
V	207.30	98.50	00.50	3.10	58.30	170.40	123.60
VI	44.10	5.10	140.40	111.10	30.20	32.70	156.70
Total	464.90	339.90	300.80	261.70	348.30	553.00	479.30

	N_3PK	Total
Block I	37.80	365.80
II	108.90	590.80
III	73.60	380.10
IV	5.00	456.50
V	8.10	669.80
VI	154.40	654.70
Total	369.80	3117.70

Comp.	D.F.	S.S.	M.S.	F
Blocks	5	(c) 11800.28	2360.06	$\angle 1$
Treatments	7	(b) 11552.89	1650.71	$\angle 1$
Error	35	(d) 82994.13	2371.40	
Total	47			

TABLE 18.

Weight of roots in third foot of soil.

Block B.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	4.4	4.0	4.00	11.8	5.8	54.5	11.1	10.9	106.5
II	17.7	11.0	8.60	109.1	28.4	41.5	2.7	7.4	226.4
III	9.3	9.3	14.30	22.9	11.4	13.0	12.2	38.4	130.8
IV	11.6	3.1	132.7	5.3	5.6	68.8	9.0	54.3	290.4
V	76.2	95.1	15.0	16.3	74.8	52.4	11.7	135.0	476.5
VI	35.2	7.9	59.7	47.7	90.4	56.5	102.3	14.1	413.8
Total	154.4	130.4	234.3	213.1	216.4	286.7	149.0	260.1	1644.4

Comp.	D.F.	S.S.	M.S.	F
Blocks	5	14004.48	2800.90	2.22 (not)
Treatments	7	3593.43	513.35	< 1
Error	35	44119.37	1260.55	
Total				

24 - 36.

Table (18) With the exception of an indication that there are significant differences between the weights derived from the 6 Sub-blocks these root weights show nothing. The weights from the respective treatments are for all practical purposes the same.

Summary:

In general it can be said that on Block B there is a deeper root system, than on the unirrigated Block C. The graph on Fig (10) shows that, whereas both blocks have an average of ± 55% of the roots in the second foot of soil, Block B has ±25% in the third foot and ± 15% in the second six inches compared to Block C, where there is an average of ± 25% in the second 6 inches and ± 15% in the third foot. The average weight from the plots of both Blocks is approximately the same as is the ratio of fine roots to heavy roots. The figures are 42 gm. of heavy roots from the Block C plots, compared to 48 from block B, 76.6 gm. of fine roots from C and 74.25 gms. from Block B. Tables (6, 7, 13 and 14)

Although these two experimental blocks stand close together on the same soil type, it must be emphasised that they are in fact two separate experiments and that direct comparisons of results cannot be made. However, because of their proximity one is justified, to a degree, in comparing conclusions drawn from the two blocks.

On Block C it is found that there is a tendency for the heavy roots to be influenced by fertilisation and that their distribution is influenced by differences in the soils, there being statistically significant differences in the weights obtained from the four sub-blocks (Table 7). In addition it was found that the weights of roots from the second 6" as well as the third foot also vary significantly on these sub-blocks (Tables 9 and 11). On Block B it is only the weights

of/.....

of roots from the second six inches of soil that show significant differences on the sub-blocks. Table (16).

This more even distribution of roots in the soil of Block B could be ascribed to one of two factors. Firstly it is possible that Block B has a more even soil structure and texture as regards root penetration, this then being not only true of the individual plots but of the block as a whole as compared to the unevenness of Block C. The mechanical analysis of the soils from these two blocks does not bear this out, nor does the general impression gained during the survey. (Table (1)) The more probable reason is that due to the presence of sufficient moisture during the otherwise dry period of the year the roots on Block B have a better chance of even distribution on what is consequently a soil more easily penetrated. On Block B those soils which tend to cement on drying will not be given the chance to do so while on Block C there is adequate opportunity for this to occur.

CHAPTER IV

SHOOT DEVELOPMENT ON THE B & C BLOCKS AND THE RELATIONSHIP TO THE ROOT DEVELOPMENT AND THE CROP PRODUCTION.

Having studied the influence of fertilization and irrigation on the development of root systems on the B and C Blocks of the B.D.V. Fertilization experiment the question now arises as to what the influence of the fertilization is on the upper plant development, and, more pertinent to this investigation, what the interrelation between the upper development, root development and crop production is. Does, for example, the large root system developed on the C Block due to the addition of P, result in a similar or proportional increase in the development of the upper part of the plant; and further, what is the influence, if any, on the crop?

This problem must of necessity be studied in the light of observations of the influences acting on the three separately. Having studied the roots and using the work of Mr. van Niekerk (8) on the crop it now remains to study the upper vegetative growth.

Again the problem of a suitable index arises and in this case the weight of shoots pruned from each plot averaged over five years was taken. As the pruning procedure is standard (Chap II) this can be considered a reliable index of the growth of the upper portion of the plant. The average weight of shoots produced on each plot over the years 1949 to 1954 were taken. These records are taken directly the shoots are pruned from the vines without being dried in any way.

Block C (dry land).

Table (19) which gives a statistical interpretation of the shoot weights derived from the respective plots, show

that/.....

TABLE 19.

Average Weight of Shoots in Kg.

Block C.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	11.86	14.52	6.26	11.96	6.84	7.32	7.56	13.66	79.98
II	11.32	10.62	12.02	17.84	11.20	11.02	8.16	16.44	98.62
III	6.80	13.12	9.66	14.58	9.88	10.92	10.32	19.14	94.42
IV	5.06	10.26	6.05	12.20	8.34	8.40	4.36	10.08	64.75
Total	35.04	48.52	33.99	56.58	36.26	37.66	30.40	59.32	337.77

	D.F.	S.S.	M.S.	F
Block	3	88.53	29.5	6.9 **
Treatment	7	213.40	30.49	7.19**
Error	21	89.06	4.24	
	31			

N.P.

	N_1	N_3	Total
-P	71.30	86.18	157.48
+P	64.39	115.90	180.29
Total	135.69	202.08	337.77

N.K.

	N_1	N_3	Total
-K	69.03	105.10	174.13
+K	66.66	96.98	163.64
Total	135.69	202.08	337.77

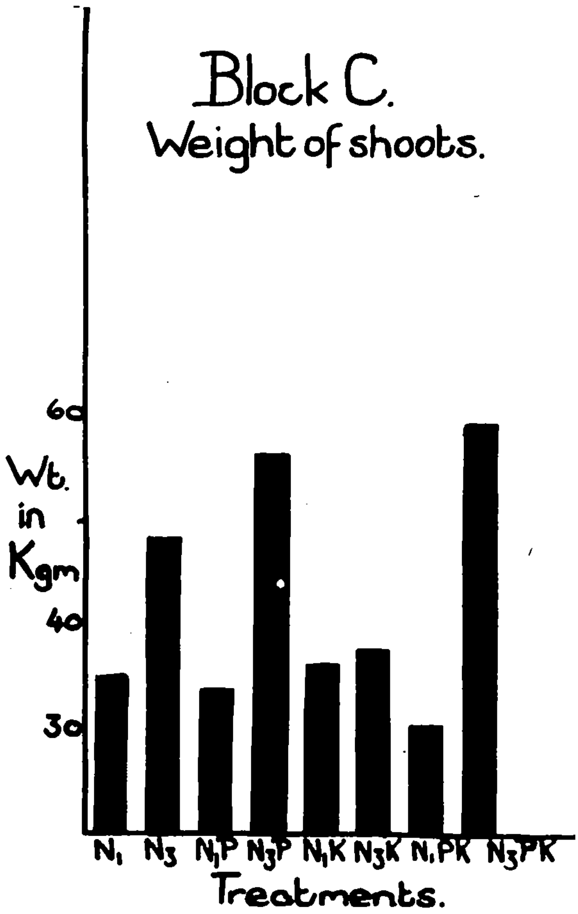
P.K.

	-K	+K	Total
-P	83.56	73.92	157.48
+P	90.57	89.72	180.29
Total	174.13	163.64	337.77

F for N = 32.48**
F for P = Not sig.
F for NP = 9.72 *

F for K = Not sig.
F for NK = " "
F for PK = " "

FIGURE 16.


Block C.
Weight of shoots.
60
Wt. in Kgm
40
30
N1
N3
N1P
N3P
N1K
N3K
N1PK
N3PK
Treatments.

that there are highly significant differences in the weight derived from the treatments. Further analysis shows that these differences are due to additions of Nitrogen and interactions between Nitrogen and Phosphate, the former being highly significant.

Fig (16) which gives a graphical representation of the weights shows clearly how these increase where N_3, the highest level of Nitrogen is applied. This applies in all cases except where Potash is added together with the N_3. Where Phosphate is added together with Nitrogen (N_3) the shoot weights increase still further - hence the interaction found on table (19).

Phosphate, despite the decisive role it plays in determining the root development on this unirrigated block, has no direct influence on the shoot weights serving only to enhance the effect of the higher Nitrogen applications. It could perhaps have been expected that, even if Phosphate did not have a direct influence on the shoot development it could, due to the influence on the root development, have had an indirect, but none the less significant, influence on the shoots. However, in shoot development Nitrogen is the most important factor and the large root development could only have resulted in the corresponding increase in shoot development when no Nitrogen is added, had it encountered large reserves of this element in the soil. This, as can be seen from the analytical data in chapter VI, is not the case with these soils. It is perhaps opportune at this point to refer to the hypothesis in the previous chapter, where the fact that the absence of Nitrogen has no effect on the root development is discussed. Potash has no significant influence on the shoot system, nor does it interact with either of the other two elements.

To/.....

TABLE 20.

Weight of Shoots divided by Weight of roots.

Block C.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	167.3	101.0	94.1	68.2	118.8	113.7	62.6	63.3	789.0
II	73.2	431.2	102.8	91.0	68.1	113.6	122.5	89.5	1091.9
III	84.2	180.5	48.4	103.3	159.9	130.3	71.1	83.9	861.6
IV	97.3	78.5	69.1	81.8	73.7	83.3	58.5	74.8	617.0
Total	422.0	791.2	314.4	344.3	420.5	440.9	314.7	311.5	3359.5

	D.F.	S.S.	M.S.	F.
Block	3	c 14531.20	4843.73	1·4 N.S.
Treatment	7	b 44493.17	6356.17	1.88 N.S.
Error	21	d 70779.77	3370.47	
Total	31			

FIGURE 17.

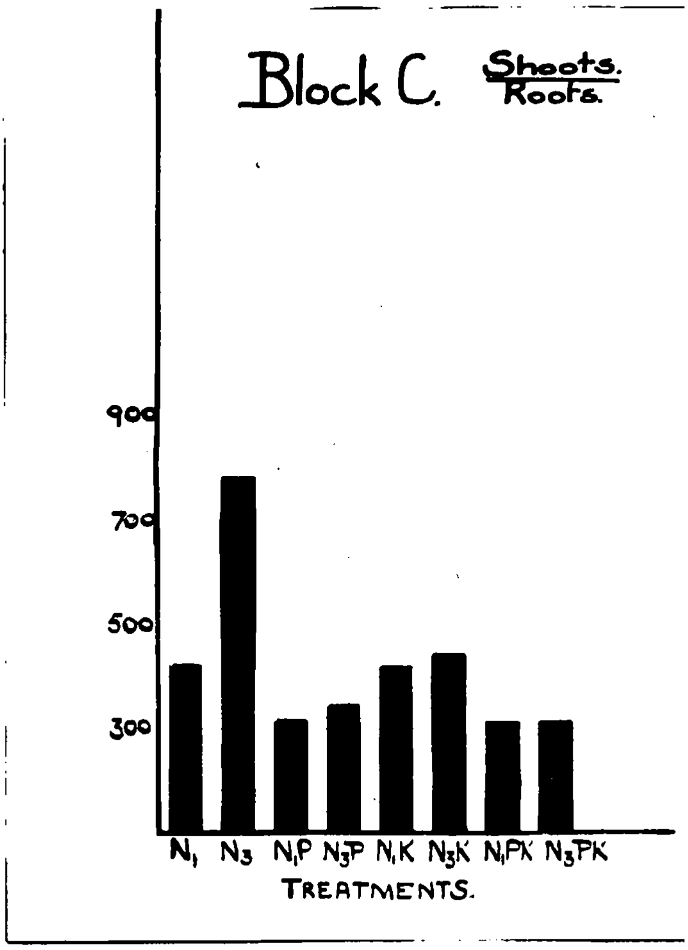
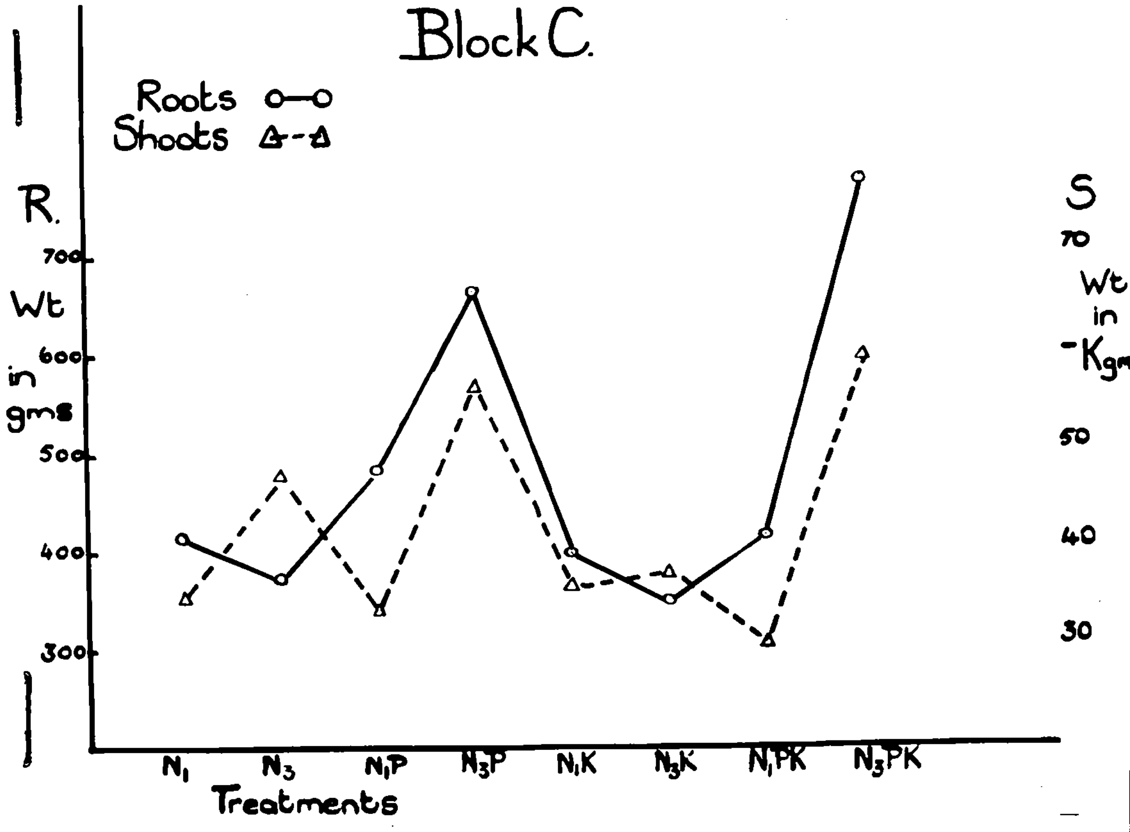


FIGURE 18.



To summarise; on the unirrigated Block C, Nitrogen plays the most important role in determining shoot development and is helped in this by additions of Phosphate. Potash plays no part. (Fig. 16).

In order to study the interaction between roots and shoots table (20) giving the shoot weights divided by root weights for each plot was drawn up. These ratios were then analized statistically as shown, but no significant differences were found.

Fig. (17) gives a graphical representation and one ratio, that of the N_3 plots, seem to be far greater than any of the others. This is due to the fact that the high Nitrogen stimulates a strong shoot development, while the root development is not stimulated in any way; and thus the balance between the two is not what would be expected. There is also a tendency for the ratios to be smaller on the phosphate treatments, which nutrient, it will be remembered, promotes root growth to such a marked degree on this block (Chap. III)

Fig. (18) gives a graphical representation of the root weights in grams and the shoot weights in Kgm. and on this the variations can be traced. It shows that peaks and valleys, in the development of these two portions of the plant by no means always correspond and thus illustrates clearly the difference in response of roots and shoots to Nitrogen and Phosphate. Fig. (19) gives the weight of roots and shoots expressed as a percentage of the average for each. On the N_1 plots the roots and shoot development is on a par, on the N_3 plots the shoot weights increase markedly while the root weights drop slightly; on the N_1P plots, despite a 20% increase in the root weights the shoot weights drop by 25%. On N_3P both are again on a par and in this case high. On the N_1K both are low but on the N_3K the root weights continue to fall while the shoot weights increase slightly/....

FIGURE 19.

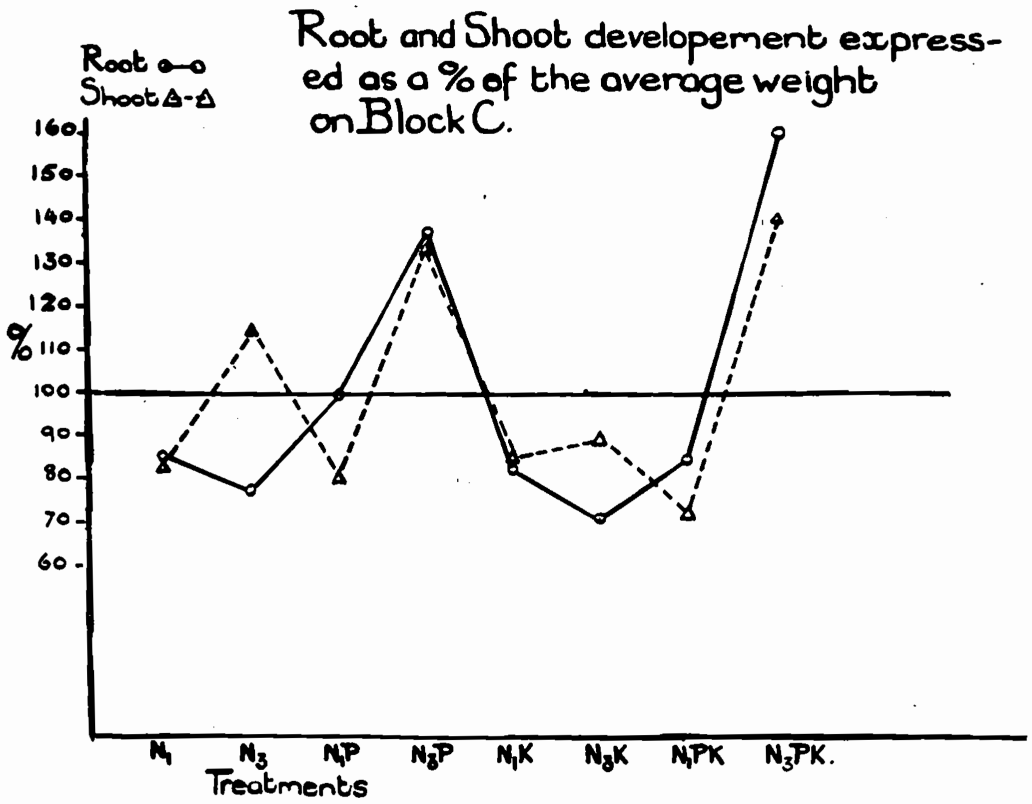
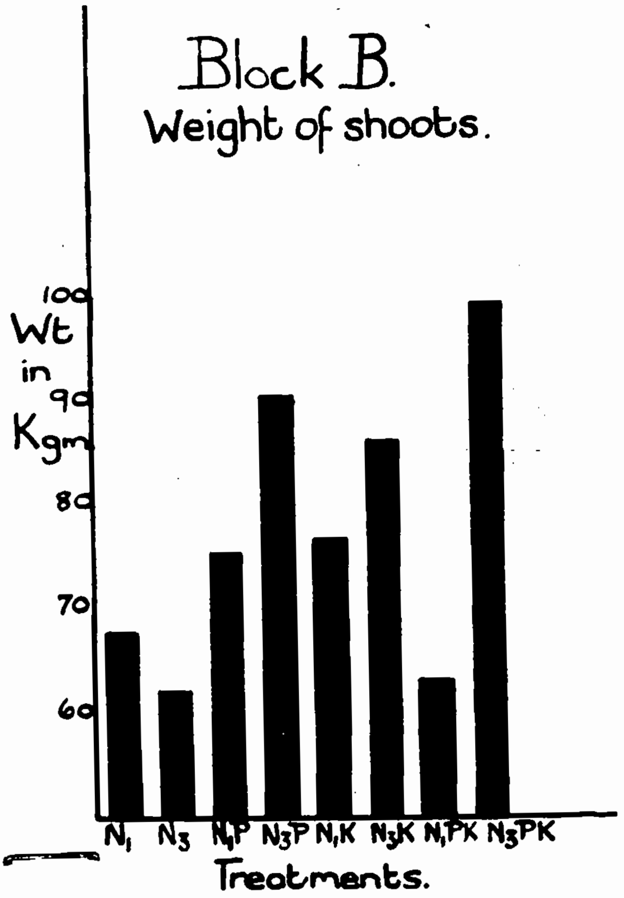


FIGURE. 20.



slightly. On the N1PK plots the position is exactly the reverse of the latter the shoot weights decreasing and the root weights increasing. The N_3PK treatments bring both to a maximum for this plot.

Gladstone (13) in 1947 discovered that the mineral nutrition of roots cultured alone differs from that of the entire plant. These results would tend to confirm his findings.

It is thus concluded that separate factors play the major role in determining the root and shoot development and that changes in one do not necessarily bring about significant changes in the other. However, it will be appreciated that in extreme cases the two components of the plant must influence one another. "In general root and shoot growth are rather closely correlated and if the growth of one is modified the other is also modified. Nevertheless considerable variation in the relative proportions of root and shoots occur, and this can be controlled by varying the conditions under which plants are grown. [11] (Kramer pp.157 (14))

Block B (Irrigated)

The statistical interpretation of the weights of shoots derived from the respective treatments is given in table (21) and according to this there are highly significant differences between these weights. Additions of Nitrogen cause a highly significant increase in the weight of shoots as does the interaction between Nitrogen and Phosphate. Phosphate on its own has a significant influence on shoot development. Further, there is a significant interaction between Nitrogen and Potash as also between Phosphate and Potash.

The exact nature of these actions and interactions is best understood with the aid of the graphical representation of the shoot weights given on Fig. (20). The first point is that additions of Nitrogen increase the shoot weights only slightly but where either Potash or Phosphate is added with the Nitrogen, the increase in shoots is marked. Phosphate alone

shows/.....

TABLE 21.

Weight of Shoots.

Block D.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	11.66	11.80	10.64	15.28	12.82	14.16	12.86	16.70	105.92
II	8.48	10.46	9.12	13.54	12.80	14.10	9.96	15.48	93.94
III	9.66	9.76	14.42	14.10	8.84	16.64	9.46	18.76	101.64
IV	9.42	7.90	15.68	15.70	13.36	10.88	8.10	17.60	98.64
V	13.50	13.82	13.94	18.82	17.92	16.92	10.86	16.12	121.90
VI	15.24	8.54	11.72	13.22	11.22	13.44	11.92	14.76	100.06
Total	67.96	63.28	75.52	90.66	76.96	86.14	63.16	99.42	622.10

	D.F.	S.S.	M.S.	F
Block	5	60.845	12.17	2.94 *
Treatment	7	210.045	30.01	7.25 **
Error	35	145.0202	4.14	
Total	47			

N.P.

	N_1	N_3	Total
-P	144.92	148.42	293.34
+P	138.68	190.08	328.76
Total	283.60	338.50	622.10

N.K.

	N_1	N_3	Total
-K	143.48	152.94	296.42
+K	140.12	185.56	325.68
Total	283.60	338.50	622.10

F for N = 15.17** F for NP = 11.55** F for NK = 6.52*
F for P = 6.31* F for K = Not sig. F for PK = 20.38**

P.K.	-K	+K	Total
-P	130.24	163.10	293.34
+P	166.18	162.58	328.76
Total	296.42	325.68	622.10

TABLE 22.

Weight of Shoots devided by

Weight of roots.

Block B.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	144.5	144.6	145.0	110.6	205.5	89.9	215.8	250.4	1306.3
II	60.0	138.5	79.4	84.4	68.9	79.7	78.6	108.6	698.1
III	171.3	74.3	132.0	137.4	168.1	94.2	151.1	157.9	1086.3
IV	88.0	68.1	103.81	211.8	175.3	70.7	80.8	251.4	1049.9
V	45.8	64.6	603.5	76.5	126.3	72.4	77.5	110.4	1177.0
VI	174.1	437.9	49.1	847.6	88.2	140.3	44.9	87.5	1869.6
Total	683.7	928.0	1112.8	1468.3	832.3	547.2	648.7	966.2	7187.2

	D.F.	S.S.	M.S.	F.
Block	5	93440.80	18691	<1
Treatment	7	102063.88	10412.	<1
Error	35	753540.76	21021	
Total	47			

shows only very slight increases in shoots weights, while Potash alone has no influence. Potash and Phosphate, added together in the absence of Nitrogen cause a sharp decrease in shoot weights. When Nitrogen is present however the three in combination produce the greatest weight of shoots.

This is contrary to the findings for Block C where Nitrogen determines the shoot development, Phosphate acts as a booster and Potash has no influence.

From Chapter III we know that statistically, fertilization has no influence on the root weights, on Block B and yet here we see the shoot weights show statistically significant response to all three elements.

In order to assertain whether there is any correlation between shoot and root development table (22) was drawn up, giving, as with block C, the shoot-divided by root weights. Statistically there are no differences between the ratio's obtained.

From the results of this table we assume that we have to do with much the same effects as those found on Block C and in order to form a clearer picture of the variations of the roots and shoots (fig. (21) was drawn up. This figure gives graphically the root and shoot weights expressed as a percentage of the average weights for the whole block respectively.

On the N_1 plots there is a shoot system thirteen percent below the average and a root system fifteen percent above the average. On the N_3 plots both fall below the average but the decline in the root development is eighteen percent while that in the shoots is only seven percent. The N_1P plots show an increase over the former but are still below the average development of both roots and shoots.

It/.....

FIGURE 21.

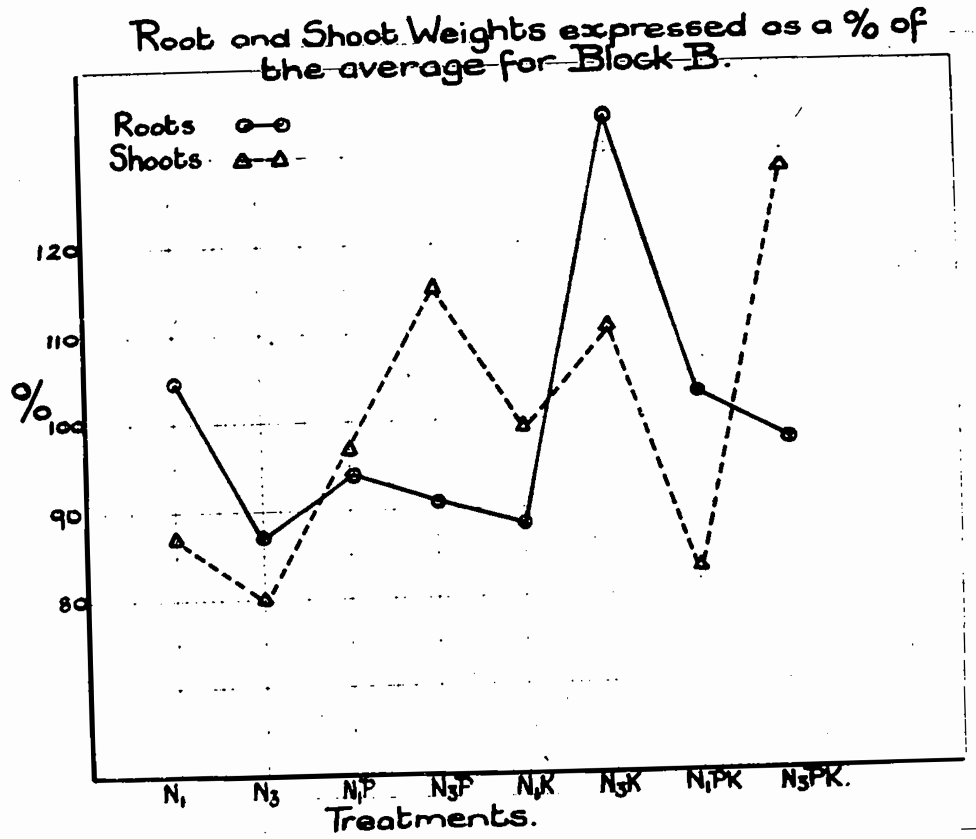
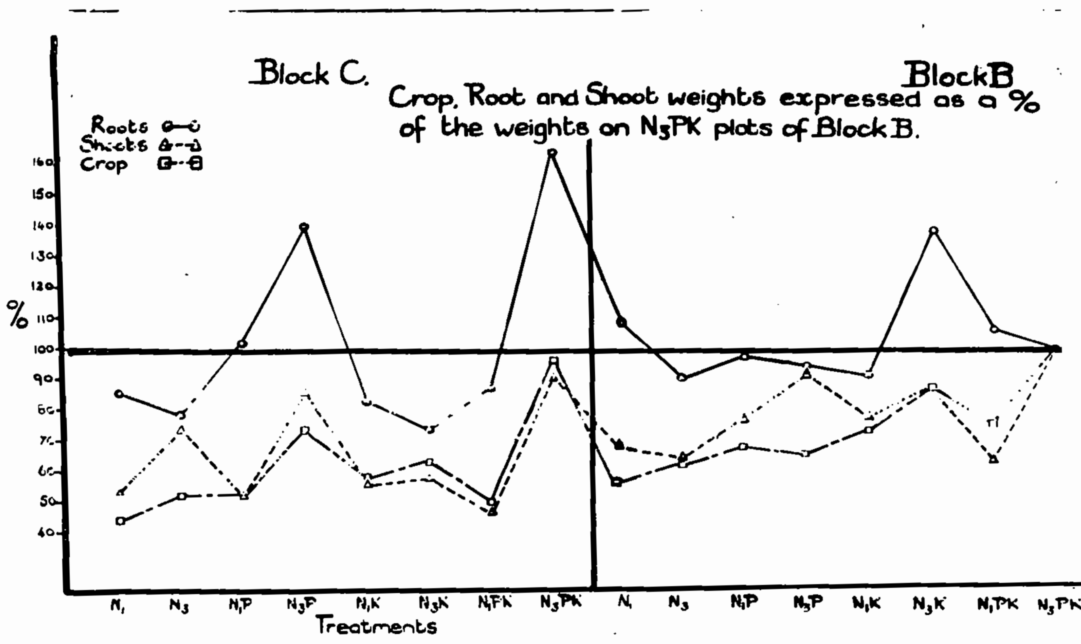


FIGURE 22.



It is on the N_3P plots that the shoot development reaches the second highest peak while the root development drops to one of the lowest values for the Block. This decrease continues on the N_1K plots where the shoot weights also decrease. On the N_3K plots a root development 35% greater than the average is found and this is accompanied by a shoot development 10% greater than the average. The N_1PK shoot development is within four percent of the lowest development found on the N_1 plots, and the root development, although it shows a sharp decline is still four percent above the average. Paradoxically the greater shoot development is found on the plots which show a below average root development - the N_3PK plots.

From these results the same conclusions must be drawn as for those found on Block C, namely that separate factors play the major role in determining the root and shoot development. The only additional fact is that, as previously observed, under irrigation different factors play the major role in determining root and shoot development.

<u>The relationship between roots shoots and crop</u>.

From the proposed thesis of Van Niekerk (8) we see that the highest crops are produced on the N_3PK plots of the irrigated block B. For this reason the weights of roots, shoots and crop produced on these plots were used as a basis for comparing that produced by the other plots. In order to do this all the weights of roots, shoots and crop were expressed as a percentage of the appropriate weights from these plots, and figure (22) giving a graphical representation of these percentages was drawn.

One of the most striking features of this graph is the fact that the shoot and crop figures show the same tendencies. This is understandable, as, the more leaf area there is, the greater is the crop that can be formed and maintained. The only place where the tendency is reversed is on the N_3P

plots/....

plots of Block B. Here the shoot weights increase to within 10% of the maximum while the crop production drops to 35% below the maximum. The reason for this is that although Nitrogen and Phosphate are present to boost growth, Potash which plays the predominant role in determining quality under irrigation is deficient. The crop weights used on this graph represent only first and second grade fruit, which cannot be produced satisfactorily in the absence of Potash, and thus, although we find crop volume is present (8), the quality is lacking and hence the decline on the graph.

Another important feature revealed by this graph is that for a moderate root system the highest crop production and shoot weights were attained. On Block C the N_1P, N_3P and N_3PK plots all produce root systems greater than that of the Block B N_3PK plots but not one of them can produce the same crop. The N_1P root weights are only one per cent higher but the crop is 50% lower while on the N_3PK plots the crop is only seven per cent lower but the root system is 60% greater. In howfar these increases in crop can be attributed to the increase in the root system and in howfar direct fertilization is responsible is not clear.

The fact that the addition of water will increase the crop by only seven per cent where full fertilization is applied tends to indicate that the very large root system produced on the unirrigated plots is successful to a marked degree in supplying the only deficient essential, water. This point will be discussed more fully a little later.

On the B Block the second highest crop is produced on the N_3K plots. Chapter II showed that on these plots the root development is extensive and it was assumed that this was due to the fact that the plant was endeavouring to obtain sufficient Phosphate. The roots are 40% greater than those of the N_3PK plots while the crop is 13% less. Also it would appear that the plant in producing a large root system has met/....

met with a reasonable amount of success although in howfar the crop is due to Nitrogen and Potash alone and in howfar it is due to the larger root system is not clear.

The rest of the plots in this Block have a smaller root development than the N_3PK plot and the crops are between 30 and 40% lower. This is with the exception of the N_1 and plots where the roots are 7 % greater and the crop 45% lower.

As noted above, the N_3PK plots on the unirrigated plot produce a crop only 7% less than those of the same plots of the irrigated Block. According to this there is thus little point in the extra expense of irrigation. However, as is often the case there is the danger of drawing a hasty conclusion before all the relevant facts have been examined. During the early years of this experiment (1946) it was found that the irrigated plots produced up to 160% (8) more than the unirrigated plots. As the years passed the latter's crop remained steady while that of the former has declined continually. The reason for this is in the balance of the nutrition.

The pH of the soil on both the blocks has decreased (15) and this has resulted in a Manganese toxicity. Table (23). The excessively high Potash fertilisation has resulted in a Magnesium (17) deficiency, while the excess of Phosphate has most probably brought about a zinc deficiency. The first two facts are deduced from foliage diagnosis and confirmed by plant analysis (Table 23) Due to the excessive signs of Mg deficiency and zinc deficiency cannot be deduced from a foliage diagnosis. The tremendous ratio of Mn to Fe shows the Mn toxicity.

The Block C N_3PK plots, although exposed to the same disadvantages of unbalanced fertilisation as those on Block B, have the advantage of an extensive root system which is able, to a degree to balance the nutrient uptake even though soil conditions are unfavourable (16). They are thus able to minimise the disbalance in the soil and maintain crop production while the outwardly more favoured Block B N_3PK plots cannot do the same. The power of a plant to extract Zn from a soil depends on the extensiveness of its root system. (11)

Kramer (14) states that at least 50% of the plants root system is redundant and can be removed without great harm being done to it. From this the inference is that a large amount of plant energy is wasted in root growth and that agricultural practice which encourages extensive root development is misguided. Thus one of the factors in increasing crop production under irrigation would be the consequent diminution of the energy and material required for the root system. This investigation reveals that the root system can decrease by 60% and still produce a larger crop, but as seen above the small root system is then very sensitive to nutritional balance. To summarise, the following points can be made.

1) Under unirrigated conditions the plant wastes a good deal of energy in pursuit of water.

2) Under irrigation this necessity is removed and consequently more energy is available for shoot and crop production but the price is a greater sensitivity to nutrient balance.

It has been stated that the great increase in the incidence of trace element deficiensies in the Western Cape can be ascribed to:

1) Lack of sufficient organic material.
2) Over-liming of the soil.
3) Over application of available Phosphate to the soil.
4) Kareemanure (Personal communication - Beyers and van Niekerk)

To this must be added in the light of this investigation (5) increase in irrigation due to

(a) The leaching effect on the soil,

(b)/

TABLE 23.

ANALYSIS OF PLANT MATERIAL

LEAF PETIOLES OF BARLINKA VINES 1954

(ON DRY WEIGHT)

BLOCK B	% N	% P	No %	% K	Mn ppm	% Ca	Fe ppm	% Mg	Cu ppm
N_1	0. 6286	.0815	.248	1.46	1790	2.80	76	.725	83
N_1P	.6272	.1060	.265	1.03	1890	2.80	75	.875	78
N_1K	.6440	.0875	.178	5.15	1090	2.15	74	.312	97
N_1PK	.6524	.1220	.200	5.25	1763	2.32	75	.300	103
N_3	.6146	.0775	.265	1.18	2840	2.62	65	.600	87
N_3P	.6804	.1040	.269	1.34	3060	3.02	70	.637	81
N_3K	.7028	.0930	.223	5.48	3770	1.96	67	.310	90
N_3PK	.6790	.0960	.160	5.05	2650	2.04	60	.325	79
BLOCK C									
N_1	.5598	.0805	.239	1.26	1700	2.66	65	.625	94
N_1P	.5530	.1205	.221	1.57	1660	2.58	53	.585	79
N_1K	.6244	.1040	.181	5.66	1240	1.77	46	.206	77
N_1PK	.6132	.1230	.152	5.50	1550	1.88	56	.137	83
N_3	.6328	.0930	.234	1.60	3980	2.48	62	.475	90
N_3P	.6748	.0880	.282	1.44	3980	3.04	64	.540	79
N_3K	.6720	.0935	.178	5.85	4250	1.76	43	.225	57
N_3PK	.6216	.0935	.159	4.83	4390	2.24	57	.255	81

(b) The diminution of the root system and consequent increase in sensitivity to nutritional disbalance.

SUMMARY OF CHAPTERS II AND III

On the unirrigated Block C Phosphate plays the major role in determining the extent of the root system. Applications of phosphate increase the system considerably and this effect is enhanced by applications of Nitrogen.

When the roots are divided into those of ¼" and greater and those less than ¼" then it is found that both Nitrogen and Phosphate play the major role in determining the extent of the smaller roots. In the case of the roots greater than ¼" Phosphate alone tends to influence their development while the weights from the respective subblocks differ significantly.

With regard to distribution no fertilization at all makes for a larger root system in the top 6" of soil. Applications of phosphate in the absence of Nitrogen and Potash result in the greatest concentration of roots in the second 6" of soil. Differences in the soil texture on the respective sub-blocks also play a role in this layer. Where Potash is added to Phosphate the root system is greater by a narrow margin than where Nitrogen is also present.

The largest root concentration is in the second foot of soil on all the treatments, uninfluenced by fertilization.

In the third foot of soil there is a small root concentration apparently influenced by the winter water table and the physical properties of the soil.

On the irrigated Block B the only fertilisation stimulus is the absence of Phosphate which results in a greatly increased root system.

The/.....

The root distribution even of the heavy roots is not influenced by differences on the respective sub-blocks although as far as physical make-up is concerned the two Blocks B and C appear to be similar.

On neither the B nor the C Block does a consequent correlation exist between the root and shoot development. Separate factors play the dominant role in determining the development of these portions of the plant.

On Block C it is Nitrogen which plays the most important role in increasing shoot development. Phosphate serves to boost this effect.

Block B on the other hand has a shoot development determined by both Nitrogen and Phosphate with Potash showing a strong interaction with both. Potash together with Phosphate in the absence of Nitrogen depresses the shoot development. There is a strong correlation between shoot development and crop production on both plots.

Irrigation makes for a larger crop on what is a relatively small root system but this increases the susceptibility to toxisities and deficiensies due to disbalance of nutrients.

CHAPTER V.

THE CITRIC ACID SOLUBLE FRACTION OF THE SOIL PHOSPHATE.

For the past fifteen years those plots on the Bien Donne experiment, Blocks B and C, indicated with the symbol P_2 have been receiving dressings of super-phosphate at the rate of 600 lbs. per morgen per year. (For convenience in the text the symbol is designated as P as there is little danger of confusion, there being only one level of Phosphate. The same applies to K_2 which is given as K). That these dressings of super-phosphate have had a profound effect on the vines is obvious from the two previous chapters, and it is the aim of the investigation described in this, as well as the following chapters to determine what the soil mechanism of this influence has been. That is to say what effect these applications of phosphate have had on the soil, which is after all, the medium from which the plants must obtain their nutrient supplies.

The first and most obvious problem to be investigated is the influence these applications have had on the Phosphate status of the soil. Secondly, and of equal importance, is the effect of other fertilizers on this soil phosphate. Obviously it is not the total soil Phosphate that is of the greatest importance but the available Phosphate and thus, before the work can be tackled a method of extraction must be chosen which will give a Phosphate fraction of the soil bearing some relation to plant growth.

Williams (18) proposed a method for fractionating soil Phosphate. Briefly, this method involves the use of 2.5% acetic acid, together with 1% 8-hydroxy Quinoline to prevent the re-adsorption of Phosphate which takes place in an acetic acid extract. This is followed by an extraction with .1N Sodium Hydroxide. This latter extract can then be split into an organic and an inorganic fraction by precipitating the organic material with Hydrochloric acid.

According to the results obtained there is a good correlation between the Acetic Acid Soluble phosphate and plant growth. There is also similar correlation found with the inorganic fraction of the sodium hydroxide extract. However, the organic fraction shows no correlation with plant growth at all. The general trend of Phosphate investigation seems to be toward a splitting of soil phosphate, by means of different extracts, into fractions which bear some relation to the state in which the phosphate occurs in the soil and hence, theoretically to plant growth.

Dean and Rubins (19) give a very comprehensive review of the phenomenon of anion exchange in the soil and draw some very revealing conclusions from their work. They tackled the problem of anion exchange of the soil in much the same way as the Cation exchange is done and in this study added greatly to the sum of knowledge of the phosphate forms of the soil. To quote from their conclusions; "The exchangeable Phosphate is a fraction of soil Phosphate which may be separated with the little interference from the other fractions and its chemical properties in relation to properties in general may be readily investigated". They go on to study the practical value of this fraction and conclude: "The anion exchange data are probably better applied as complementary data than as a substitute for the conventional available Phosphate."

From this it is concluded that any survey of soil Phosphate is best conducted with the help of a proven method, that is, one which shows good correlation with plant growth. In order then to increase the value of

such/....

such a survey, other fractions can be determined and viewed as complementary to the initial extract.

In this survey 1% sitric acid was chosen as the basic method. With soils having a pH of 5 and lower the use of sodium hydroxide, which would radically change the pH of the soil and thus inevitibly introduce secondary changes could not be considered. In an article Vink (20) reviews the relative merits of citric and acetic acid extractions and concludes that citric acid is for all practical purposes the best. Further although there is a dearth of work on the correlation between soil extracts and deciduous fruit tree growth, work in this country shows a good correlation between the annual crops and the citric acid soluble fraction of the soil phosphate (21).

In their work on the anion exchange capacity of the soil Dean and Rubins (19) investigated the exchanging powers of the anions Arsenate, Fluoride, Hydroxide, Citrate, Tartrate and Acetate. A summary of their findings is as follows:-

1) Soils have an anion exchange capacity in that they can be alternately saturated with Arsenate and Phosphate ions.

2) P in the exchangeable form is only virtually completely removed by Fluoride Hydroxide and Citrate solutions, although in the latter case anion exchange is probably not involved.

3) Anion exchange capacity of the soil increases with clay content of the soil and when free iron oxides are remoed chemically from the soil there is a reduced anion exchange capacity which is however not proportional to the amounts of iron oxides dissolved.

Because of this latter point the indirect method of determining anion exchange capacity proposed by Bass and Sieling (22) is not viewed favourably. (They

claim/....

TABLE 24.

BLOCK C.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

0" - 9" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total.
Block I	15.9	8.6	45.2	35.8	10.4	13.1	42.5	45.1	216.6
II	18.1	13.5	36.3	19.2	20.0	20.8	28.7	30.0	186.6
III	25.1	20.2	45.2	43.5	16.9	15.1	54.2	47.2	267.4
IV	55.9	21.2	75.0	75.5	19.3	15.6	49.3	72.0	383.8
Total	115.0	63.5	201.7	174.0	66.6	64.6	174.7	194.3	1054.4

F = 5.79 ** for treatments
F = 7 ** for blocks.

NP

	N_1	N_3	Total.
-P	181.6	128.1	309.7
+P	376.4	368.3	744.7
Total	558.0	496.4	1,054.4

NK

	N_1	N_3	Total.
-K	316.7	237.5	554.2
+K	241.3	258.9	500.2
Total	558.0	496.4	1,054.4

PK

	-K	+K	Total.
-P	178.5	131.2	309.7
+P	375.7	369.0	744.7
Total	554.2	500.2	1,054.4

F = for N
F = 36.7** for P
F = <1 for NP.
F = <1 for K.
F = 1.82 not sig. for NK.
F = 4.17 not sig. for PK.

claim that by extracting the soluble iron and aluminium compounds of the soil the anion exchange capacity can be determined. (For this survey 1% Citric Acid was chosen as well as the NH_4F - HCl extracting agent in order to have two separate assessments of the available phosphate status of the soils.)

The following is a discussion of the citric acid figures for the Blocks B and C.

Block C. (non-irrigated).

0" - 9".

The figures in Table (24) represent the 1% citric acid soluble Phosphate found in the top 9" of soil. They show highly significant differences between the treatments and as could be expected these are mainly due to the tremendous increase in Phosphate on those plots where additions of Super-phosphate were made. Further analyses of the figures show that none of the other elements added have a significant influence on the phosphate content of the soil. In the case of Potash there is an indication of an interaction with Phosphate. This interaction seems to be brought about by the fact that where Potash is added in the absence of Phosphate there is a decrease in the Phosphate content of the soil as compared to soil which has received no P and K fertiliser. The total citric acid soluble Phosphate on all the plots which receive Potash is 500 p.p.4m. while the total of those plots receiving no potash is 554.2 p.p.4m., a difference of 54.2 p.p.4m. (Table 24) It can be seen that this difference is due mainly to the fact that there is a considerable amount of phosphate found on the K_1 plots and this again in main is due to the large amount of phosphate found on the Block III and IV K_1 plots. In other words this indication is a product chiefly, of the heterogenity/....

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heterogenity/....

FIGURE 23.

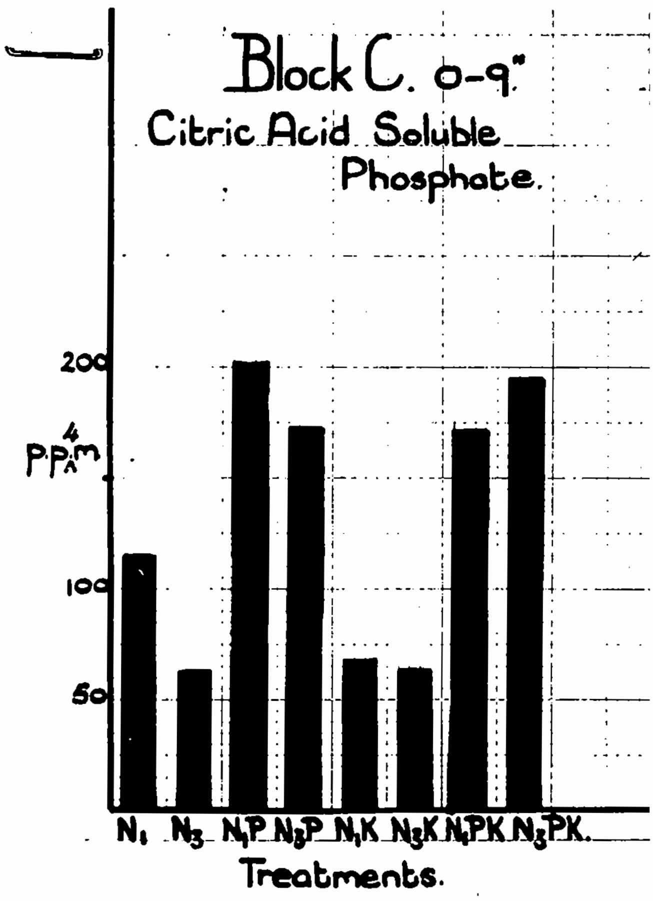
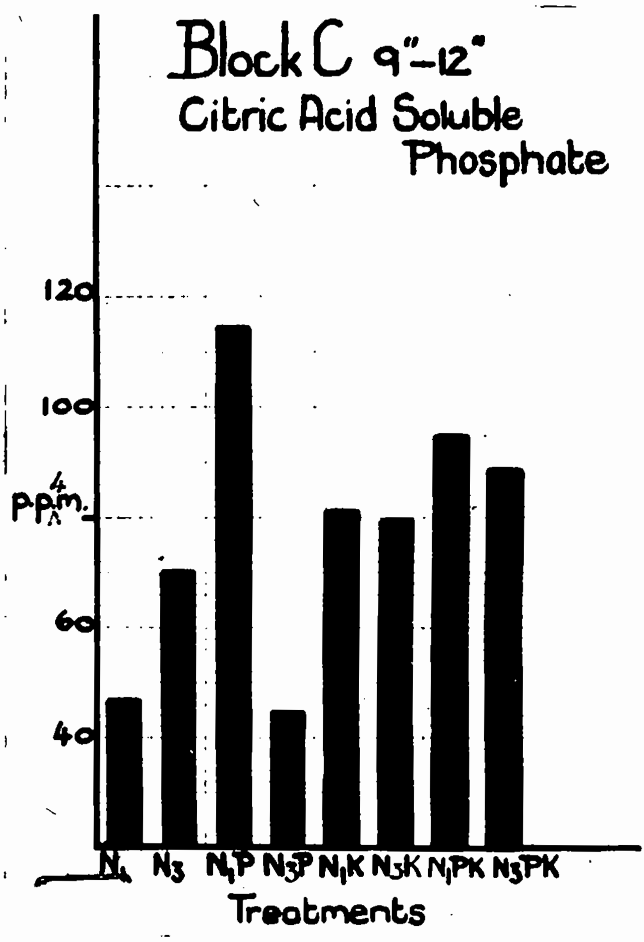


FIGURE 24.



heterogenity of the soils and is due purely to chance.

A fact that can also have some bearing on the case is that on those plots receiving dressings of Potash there is a greater % of Phosphate in the plant material. (Table 23) as compared with those which receive no potash. Thus a possible explanation for the loss of this Phosphate is that it has been used by the plants and an analysis of the plant material shows that their % phosphate increases with applications of Potash (Table 23).

Figure 23 which gives a graphical representation of the total citric acid soluble Phosphate of four plots in the top 9" of soil for each treatment illustrates the statistical findings. In fact the figure reveals additional information which is not immediately obvious from the statistical analysis: The unfertilised or N_1 plots have a relatively high Phosphate content in the top soil, while the N_3 plots are as low as the N_1K and N_3K totals, due possibly to the bigger P uptake on these plots. Due to the fact that this is the first time the soils have been sampled in this way it is not possible to trace the change in the phosphate content of the soil over the years. One other fact that emerges from the statistical analyses is that the upper layers of soil from the respective subblocks show statistically significant differences as regard to their Phosphate content. This can only be due to the fact that the original Phosphate status of these soils varied, subblock 4 being the richest. The lower layers show no such difference, Tables 26, 27 and 28).

9 - 12".

The amounts of Phosphate extracted from this layer of soil show, as with the top soil, significant differences between the amounts from the respective treatments. These differences are due to an interaction

between/.....

TABLE 25.

BLOCK C.

% Sesquioxides soluble in 22% HCl. in 0 - 9" of Soil.

N_1	3.80%
N_3	3.55%
N_1P	3.46%
N_3P	3.78%
N_1K	3.74%
N_3K	3.49%
N_1PK	3.90%
N_3PK	3.85%

These values represent averages from the four repetitions of each treatment.

TABLE 26.

BLOCK C.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

9" - 12" of Soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	4.6	6.5	21.5	8.1	18.0	13.1	18.1	24.0	113.9
II	10.7	12.4	36.3	6.5	14.8	22.7	9.9	11.8	125.1
III	18.7	35.0	25.0	10.7	20.2	25.3	43.2	23.7	201.8
IV	13.1	16.4	31.7	17.5	28.7	18.7	24.0	29.2	179.3
Total	47.1	70.3	114.5	42.8	81.7	79.8	95.2	88.7	620.1

$F = 2.87^{x}$ for treatments.

NP	N1	N3	Total.
-P	128.8	150.1	278.9
+P	209.7	131.5	341.2
Total	338.5	281.6	620.1

NK	N1	N3	Total.
-K	161.6	113.1	274.7
+K	176.9	168.5	345.4
Total	338.5	281.6	620.1

PK	-P	+P	Total.
-K	117.4	157.3	274.7
+K	161.5	183.9	345.4
Total	278.9	341.2	620.1

$F = 1.99$ not sig. for N.

$F = 2.40$ for P.

$F = 6.25^{x}$ for NP.

$F = 3.1$ not sig. for K.

$F = <1$ not sig. for NK

$F = <1$ for P.K.

between Nitrogen and Phosphate. Where Phosphate has been added in the absence of Nitrogen there is a higher concentration of Phosphate than is found on any of the other plots. Where Phosphate has been added together with Nitrogen the Phosphate content is about the same as for those plots where no phosphate has been added. (This is with the exception of the N_1 plots where the Phosphate content is extremely low).

In addition to this effect there is an indication that on those plots where Potash has been added there is more Phosphate in this layer of soil. Once more this effect of Potash can be traced to the N_1 plots. In this case it is the extremely low value for these plots which results in the indication of there being more Phosphate on the plots which receive Potash but no Phosphate. (Table 26).

Figure 24 giving a graph of the Phosphate in this layer of soil illustrates the above discussions. The plots receiving Phosphate and no Nitrogen show a far greater Phosphate content than those receiving both Nitrogen and Phosphate, due entirely to the fact that on the N_1P plots the P content is in total greater than on the other treatments. In this layer the results are extremely erratic which detracts from the value of the findings, but in all cases the N_1P plot has the highest or nearly the highest value for the block in which it is situated. Thus despite erratic results on the other plots the phosphate in the N_1P plots remains consequently high.

The higher Phosphate content found on the N_1P plots could be accounted for by one of the following possibilities:

It can be assumed that on all the other plots the growth is stronger than on the N_1P plots thus result-

ing/....

resulting in a greater exhaustion of this layer leaving the N_1P plots the richest. Previous work shows that at least the N_1 N_1K and N_1PK plots have a lower growth rate than the N_1P plots (Chapters III & IV) thus the above could not be the case. There must thus have been an enrichment of this layer from the added Phosphate. The implication is thus that phosphate is not in fact static in these soils but moves. As this is contrary to the accepted theory of Phosphate as a static fertilizer far more evidence will have to be advanced to support the statement, and it is hoped that this survey will supply some of the necessary evidence.

If one accepts for the moment this concept of a mobile phosphate, then why is it that the N_1P plots are richer than the other phosphated plots? There are two possibilities.

(1) On the N_1P, N_3P, N_1PK and N_3PK plots the water soluble fraction of the added fertilizer was able to move into this layer before being bound by the soil. The large concentration of Phosphate in the top soil would allow this to happen reasonably easily.

Due then to the greater growth rate and production of the N_3P plots the Phosphate in this lower layer (9 - 12") of these plots has not been allowed to accumulate.

(2) Due to some effect of ammonium sulphate, Phosphate has been taken into solution and has moved evenly through the entire soil profile. It is not detected by analysis due to the fact that it is such a small amount in a large volume of soil in which roots are feeding actively. In other words the Nitrogen is capable of accelerating the postulated movement of P.

When the root systems developed by the vines on the respective plots are taken into account the point (2) emerges as a very logical possibility. It is known from Chapter III that Phosphate plays a very important part ..

in Block C in determining the extent of the root system, thus of the success with which the plants are able to obtain moisture and thus of the general performance of the plant. Because of this fact it is assumed that the plant root system would develop so as to facilitate maximum uptake of Phosphate and once having achieved this would then develop towards moisture. In other words development of the root system would be limited unless sufficient Phosphate could be obtained. The high concentration of roots in the relatively shallow layer of the second 6" of soil on the N_1P plots at the expense of the deeper and what could be termed 'water-finding roots", must indicate that on these plots large amounts of Phosphate can only be obtained from this shallow layer. On the N_3P plots the root system as a whole is larger than the N_1P plots but in the case of the former there is a smaller weight of roots in the second 6" of soil than there is in the latter. If point (1) held good then the least that could be expected would be an equal concentration of roots in the shallow layers of the N_1P and N_3P plots.

The degree to which the presence of P can influence the root distribution is further emphasized if one considers the N_1 plots. Here we find the highest concentration of Phosphate, of the non-phosphated plots, in the top 9" of soil and of all the plots these have the highest % of roots in the initial 6" of soil. The lower layers of these plots are extremely poor in P thus the only really strong source of P is this upper layer. The Phosphated plots have high % of P in the upper layers but the root concentration is not great here because sufficient P can be obtained from lower layers more hospitable to a root development/.....

TABLE 27.

BLOCK C.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

12" - 15" of Soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	4.1	5.9	15.9	8.3	18.0	6.5	7.3	12.2	78.2
II	12.7	11.9	8.2	7.8	7.3	20.2	8.2	7.6	83.9
III	11.8	21.2	20.2	11.5	18.3	11.8	19.5	28.3	142.6
IV	11.9	20.2	19.5	18.3	25.0	15.9	20.2	6.5	137.5
Total	40.5	59.2	63.8	45.9	68.6	54.4	55.2	54.6	442.2

F = ~~LT~~ <1 not sig. for treatments.

TABLE 28.

BLOCK C.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

15" - 18" of Soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	3.4	3.8	9.8	8.1	8.3	4.4	3.6	6.8	47.8
II	5.2	9.6	2.7	3.3	5.4	15.1	2.9	6.5	50.7
III	5.2	10.8	16.4	9.6	15.1	5.8	12.4	8.6	83.9
IV	11.4	16.4	14.8	17.5	15.9	10.8	18.7	16.8	122.3
Total	25.2	40.6	43.3	38.5	44.7	36.1	37.6	38.7	304.7

F = ~~LT~~ <1 not sig. for treatments.

Point (2) is thus a feasible explanation for what has happened to the phosphate. In passing mention must be made of a point raised by Le Roux (personal communication 1954). He states that the general impression gained by himself in practise is that the 'Jacques' rootstock is susceptible to drought. A recent survey by the D.F.B. 1952 shows that in the whole Western Province there is not a single area where the fertilization program does not consist of an excess of Phosphate with little or no Nitrogen and Potash. Under these conditions it has been seen that 'Jacques' forms a very shallow root system thus accounting for the general impression of a non-drought resistant root stock. Theron (24) in an article in the 'Landbou Weekblad' confirms Le Roux's observations.

12" - 15".

Statistically there are no differences between the amounts of Phosphate from the respective treatments in this layer of soil. All the soils are equally low in Phosphate with the exception of the N_1 plots which are even lower than the rest. The same applies to the succeeding layers 12" - 15", 15" - 18" and 18" - 24" (Tables 26, 27, and 28).

When the layers 9" - 12", 12" - 15" and 15" - 18" are grouped together and tested statistically then no significant differences (Table 29) are found. This fact considerably weakens the case for the theory of the mobilization of P by N but if one considers that the P involved is most probably spread over a total depth of 24" in which the root concentration is high this fact does not completely negate the theory.

Of/.....

TABLE 29.

BLOCK C.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN p.p.m.

9" - 18" of Soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
Block I	12.1	16.2	46.8	24.5	44.3	24.0	29.0	43.0
II	28.6	33.9	21.2	17.6	20.9	58.0	21.0	25.9
III	36.4	53.0	66.0	56.7	69.6	45.4	62.9	52.6
IV	35.7	107.0	61.6	60.6	53.6	42.9	75.1	60.6
Total	112.8	210.1	195.6	159.4	188.4	170.3	188.0	182.1

	Total.
Block I	239.9
II	227.1
III	442.6
IV	497.1
Total	1,406.7

F = <1 not sig. for treatments.

Of interest is the fact that those plots receiving Phosphatic fertiliser show a slightly higher total of available Phosphate in the lower layers than those which do not receive Phosphate. 713 p.p.7m. compared to 680 p.p.7m.(Table 29). This difference is however not significant.

Discussion.

In the previous pages it has been suggested that phosphate is mobile in the sandy soils of Bien Donne with their low fixation capacity. (The average % Sesquioxides is below 4% Soluble in 22% HCl (Table 25)) Further it has been suggested that additions of ammonium sulphate accelarate this movement.

Firstly the movement of Phosphate can be accounted for by the supposition that the upper layers of the soil, the initial 9", have become relatively saturated with phosphate and that as a result a fraction of the partly water soluble phosphate of the added Supers is leached through this layer before it is bound in the following 3" of soil. This would account for the enrichment of the 9" - 12" layer of the N_1P plots. But in addition to this movement there is the far stronger movement postulated for the plots receiving additions of Nitrogen which cannot be accounted for in this way. (Bearing in mind always that this "loss" could be accounted for by the greater uptake of P by the plants on those plots receiving the higher rate of Nitrogen and hence having a greater growth rate.)

Before advancing a possible explanation for this movement, consider the nature of forms in which phosphate occurs in the soil. Soil Phosphate can be grouped into three types, each of which is in equilibrium with the other. The position and balance of this equilibrium

depends/....

depends on the soil and the treatment it receives.

$$\begin{tikzcd} \text{Fixed or unavailable P} \arrow[rr, shift left] \arrow[dr, shift left] & & \text{Exchangeable P} \arrow[ll, shift left] \arrow[dl, shift left] \\ & \text{Soluble or Ionic P} \arrow[ul, shift left] \arrow[ur, shift left] & \end{tikzcd}$$

If there were an increase of the ionic P in solution then it is conceivable that this could be removed by leaching in the same way as any soluble substance. If the complexes which fixed the soluble P were to be largely saturated and heavy additions of soluble P were made then such a leaching would be possible. Further if some substance were added which could increase this ionic fraction then the same result could be expected. Ammonium Sulphate is advanced as possibly being such a substance. As stated previously, the fact that this movement of Phosphate cannot be determined by means of analysis, considerably weakens the case for the mobilization of P by Ammonium Sulphate.

Islam (25) shows with the help of pot experiments that on a soil with a low P fixation capacity Phosphate can be washed out in sufficient quantities to support plant life, which to a degree supports the findings on this experiment.

In Chapter VII a total economy of the Phosphate on the C Block is given and here it will be seen what the magnitude of the loss is from the top 12" of soil on those plots receiving the higher level of N. In chapter VI a possible explanation of the mechanism of the influence of Ammonium Sulphate is given.

In Chapter VII it will be seen that the loss of phosphate due to application of Nitrogen is definitely an interaction between Nitrogen and applied phosphate.

From Table 24 it is apparent that the average % of Citric Acid Soluble Phosphate found in the top 9" of those plots which receive dressings of phosphate is .0047% P. Those which receive no phosphate dressings have

.0019%P/.....

.0019%P. From the work of Malherbe (21) we know that .0033%P is considered as the critical value for a poor soil (annual crops). The subsoil 12" - 24" of both phosphated and non-phosphated plots is .0015% and .0014% respectively, both far below the critical value established.

Given only these figures for a fertilization diagnosis the recommendation would be that both soils receive dressings of phosphate fertilizer although the rate would be a bit lower in the case of the former. This despite the fact that the vines on the phosphated plots are suffering, if, from anything, from an excess of Phosphate. This must clearly illustrate the danger of making a fertilization requirement diagnosis for perennial tree crops from nothing but a soil analysis.

The limiting factor in production on all the plots is at the moment rather the strong Magnesium and possibly Zinc deficiencies coupled with a toxic effect from the Manganese (Table 23).

Block B (Irrigated).

Under irrigated conditions the same applications of Phosphate do not play as important a part in promoting root grwoth as under unirrigated conditions (Chapter III).

According to the figures shown in Chapter III and IV Phosphate plays the major role in determining the root development on Block C, but in the case of the shoot development it is on Block B and not on C that the major influence of Phosphate is found. With regard to the crop (8) (Chapter IV) it is found that both on B and C, it plays a part but on C it assumes a greater importance than on B.

The only fertilization influence that can be found on the roots on Block B is an indication of an interaction between P and K brought about by the increased root system found on those plots receiving Nitrogen and Potash but no Phosphate. (Chapter III.) Thus on this/....

TABLE 30.

BLOCK B.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN p.p.m.

0" - 9" of Soil.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$	Total.
Sub Block I	26.0	16.4	19.8	42.2	14.4	12.4	26.3	43.8	201.3
II	16.2	9.1	59.8	31.7	8.4	12.7	23.4	20.2	181.5
III	5.4	6.3	36.3	38.2	5.1	7.9	17.0	33.8	150.0
IV	10.3	17.8	68.0	42.0	9.9	10.6	44.0	54.2	256.8
V	7.6	14.8	30.8	49.3	8.0	15.5	58.0	19.0	203.0
VI	17.5	15.3	56.0	60.8	12.7	20.8	44.0	43.2	270.3
Treatment Totals.	83.0	79.7	270.7	264.2	58.5	79.9	212.7	214.2	1,262.9

F = 9.45 ** for treatment.

NP	N_1	N_3	Total
-P	141.5	159.6	301.1
+P	483.4	478.4	961.8
Total	624.9	638.0	1,262.9

NK	N_1	N_3	Total
-K	353.7	343.9	697.6
+K	271.2	294.1	565.3
Total	624.9	638.0	1,262.9

PK	-P	+P	Total
-K	162.7	534.9	697.6
+K	138.4	426.9	565.3
Total	301.1	961.8	1,262.9

F = 62.4 ** for P   F = not sig. for N.
F = not sig. for NP.   F = not sig. for K.
F = [illegible] for NK.   F = not sig. for PK.

this Block we have to do with an entirely different set of vegetative responses to fertilization.

0 - 9". Table 30.

As can be expected there is a highly significant difference between the treatments (Table 30) and this difference is due to the fact that those plots which have had applications of Phosphate contain far more Citric Acid Soluble P than any of the other plots. There is also a slight indication that where K is added there is less Phosphate in the top 9" of soil.

This again can be accounted for by the fact that those vines growing on the K fertilized plots with the exception of the NK contain a considerably higher % of Phosphate (Table 23) The loss amounts to 132.3 p.p.6m. for the six Potash fertilized plots. Soil heterogenity is, however, the most important factor in this respect and thus one cannot attach much significance to this indication.

Tables 31, 32 and 33 show that statistically there is absolutely no difference between the amount of Phosphate in the subsoils of the respective treatments. And when the values (Table 34) are summed there are still no differences. There are, however, a few points of interest analogous to those found on Block C.

In the first place we see that the subsoil (9" - 18") of the N_1 Plots is as poor in Phosphate as any of the other and further, from Table 30 we see that the top.soil (0" - 9") is about the same as that of any other plots which received no dressing of Phosphate. This was predicted in Chapter III, as the root system shows no tendency to develop strongly into the upper 12" despite more favourable temperature and moisture conditions than are found on Block C. The Block B root system is deeper than that of Block C (Figure 10).

<u>Summary:</u>/......

TABLE 31.

BLOCK B.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

9" - 12" of Soil.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$
Sub Block I	29.1	17.5	10.7	11.4	13.7	13.1	42.2
II	15.3	6.8	14.2	41.5	9.4	11.6	7.9
III	4.4	3.8	17.3	16.2	5.3	8.0	5.4
IV	9.9	18.2	15.5	9.3	7.9	12.1	11.8
V	8.0	11.1	7.6	10.6	6.4	12.9	10.8
VI	18.3	11.3	6.9	19.5	16.7	16.7	12.2
Treatment Totals	85.0	68.7	72.2	108.5	59.4	74.4	90.3

	$N_3P_2K_2$	Total.
Sub Block I	17.5	155.2
II	5.6	112.3
III	16.7	77.1
IV	20.2	104.9
V	5.1	72.5
VI	6.9	108.5
Treatment Totals	72.0	630.5

$F = <1$ not sig. for treatment.

TABLE 32.

Block B.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

12" - 15" of Soil.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$
Sub Block I	22.7	16.9	7.9	15.3	14.8	11.4	23.3	16.4
II	14.1	6.8	12.7	14.9	8.0	11.3	4.6	7.2
III	3.8	2.9	37.7	14.4	3.4	5.6	3.1	14.4
IV	10.3	18.2	12.9	9.3	8.6	9.9	10.8	14.7
V	7.6	10.9	8.7	19.0	6.1	12.7	14.8	4.8
VI	15.9	12.2	7.8	16.9	11.4	16.9	12.1	3.7
Treatment Total	74.4	67.9	87.7	89.8	52.3	67.8	68.7	61.2

	Total
Sub Block I	128.7
II	79.6
III	85.3
IV	94.7
V	84.6
VI	96.9
Treatment Total	569.8

$F = <1$ not sig. for treatment.

TABLE 33.

BLOCK B.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

15" - 18" of Soil.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$	Total
Sub Block I	20.2	16.2	7.1	15.5	12.9	10.1	23.3	15.3	120.6
II	12.7	3.6	6.7	9.7	4.9	10.3	2.4	6.6	56.9
III	2.9	2.6	19.0	12.7	3.8	4.1	3.8	12.1	61.0
IV	11.4	24.7	13.8	8.9	8.8	17.2	10.8	16.4	112.0
V	6.9	11.1	8.7	7.2	7.3	16.9	14.4	4.8	77.3
VI	8.2	11.4	6.7	15.0	19.0	17.5	11.8	7.8	97.4
Treatment Total	62.3	69.6	62.0	69.0	56.7	76.1	66.5	63.0	525.2

$F = <1$ not sig. for treatment.

TABLE 34.

BLOCK B.

CITRIC ACID SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

9" - 18" of Soil.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$
Sub Block I	72.0	50.6	25.7	34.6	41.4	42.2	88.8	48.2
II	42.1	17.2	33.6	66.1	21.3	32.2	14.9	19.4
III	11.1	9.3	74.0	43.3	12.5	17.7	12.3	43.2
IV	31.6	50.7	33.2	26.4	25.3	38.2	33.4	40.7
V	22.5	33.1	25.0	28.8	19.8	42.5	40.0	14.7
VI	42.4	34.9	21.4	91.4	46.1	51.1	35.1	18.4
Treatment Total	221.7	195.8	212.9	290.6	166.4	223.9	224.5	184.6

	Total.
Sub Block I	403.5
II	246.8
III	223.4
IV	279.5
V	226.4
VI	340.8
Treatment Total.	1,720.4

$F = <1$ not sig. for treatment.

Summary:

On both Block B and C additions of super-phosphate have increased the citric acid soluble P of the initial 9" of soil. Soil heterogeneity is such that some of the sub-blocks are significantly richer than others.

On Block C the N_1P plots have significantly more Phosphate in the 9" - 12" layer than any other treatments. On this, together with the evidence obtained from the root development and distribution, is based an assumption that in these soils Phosphate is not completely static but moves, although apparently the amounts are too small to be confirmed by the soil analysis but large enough to influence the root distribution. In Chapter VII more direct proof of this movement is given where the total P economy is studied. The possibility of biological movement of the phosphate via the roots is a strong one and this is also investigated in Chapter VII.

Indications of an influence of K on the soil phosphate are not of much value due to the heterogenity of the soil as expressed by the vacillating amounts of phosphate extracted from plots which have had the same treatments.

On Block C the succeeding layers deeper than 12" show no statistically significant differences at all, while on Block B the layers deeper than 9" of soil show no variations.

CHAPTER VI.

NH_4F - HCI SOLUBLE PHOSPHATE, TOTAL NITROGEN & pH.

In order to obtain a separate assesment of the available Phosphate in the soil the ammonium F - HCI method described in Chapter II was used. These values must serve as complementary to those of Chapter V as very little evidence exists for a correlation between this extract and plant production. Fourie (personal communication 1954) reports that preliminary surveys conducted with the same extracting agent gave promising results where supers had been applied to mealies.

The values are considerably higher than those obtained by the citric acid 1% extraction. Fig. 33 (Chapter VII) which gives the average values for the 1% citric acid extract, the 22% HCI extract and the NH_4F - HCI extract, illustrate the relationship that this latter extract bears to the former two. The following is a discussion of the results obtained on the respective layers of the B and C Blocks.

Block C. (: un-irrigated).

0" - 9".

The figures from this initial depth show, as in the case of the citric acid soluble Phosphate, significant differences (Table (35)). These differences are due to additions of super phosphate which result in a higher fraction of ammonium Fluoride soluble Phosphate in this upper layer. In addition there is a significant influence on the part of Nitrogen, the more Nitrogen applied the less P there is in this layer. This effect is even more pronounced where Phosphate is also added and thus there is a significant interaction between N and P.

The relevant facts are thus

(1) Applications of Super P increase the NH_4F soluble Phosphate in the first 9" of soil. (2)/....

(2) Application of Nitrogen results in a depletion of this fraction of Phosphate from the 0 - 9" layer of soil more especially where supers has also been applied.

This latter point was surmised in the preceding chapters IV and V, due to the behaviour of the root system. Here thus we have direct evidence for the 'loss' of Phosphate from the initial 9" of soil where Nitrogen is applied. The cause of this loss is however by no means clear and from the evidence the possibility of loss due to greater plant growth on these plots where both Nitrogen and Phosphate are applied is the most acceptable. However the indication given by the root system as discussed in Chapter V, and the results obtained from the total economy study, chapter VII, build a reasonably strong case for the theory of the mobilisation and consequent leaching of P by Ammonium Sulphate.

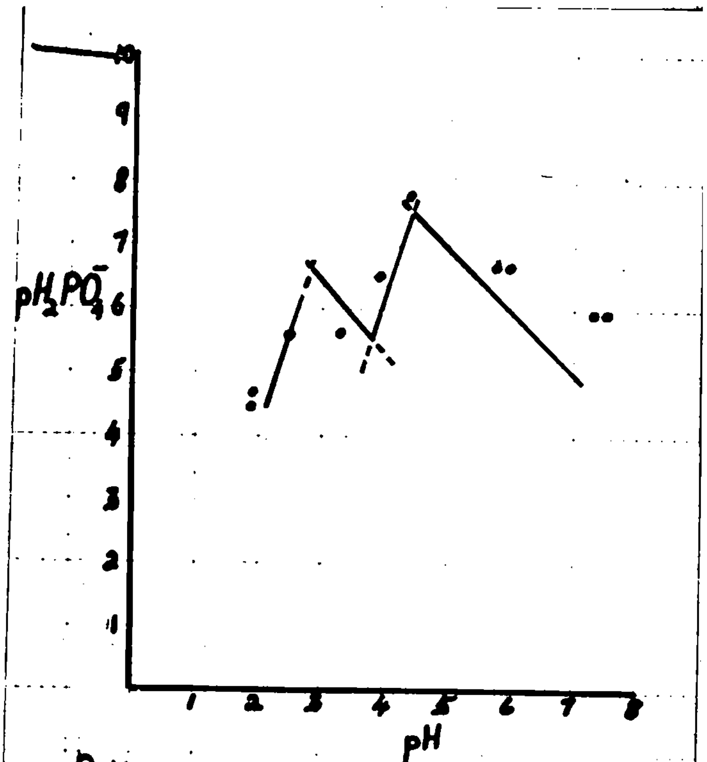
Darby (27) in his thesis states that in his opinion soil phosphate will move together with iron, under conditions favouring the solution of the latter in the soil. In the case of his findings this occurs under anaerobic conditions caused by waterlogging. He finds that phosphate accumulates in certain soil layers together with iron.

It is possible that the movement of P on the Bien Donne soils is a similar phenomenon, the solution of the iron being due in this case to the acidity induced by additions of Ammonium Sulphate. The movement postulated by Darby (27) is one which would have taken place over long periods, even centuries and thus cannot be compared directly with those found here. Nevertheless with the addition of an acidifying substance to the soil like ammonium Sulphate, an accelerated process with the same mechanism, namely the solution of the iron in the soil could have occurred.

This acidity is then not the accumulative effect measured by means of soil pH but the temporary conditions of extreme acidity induced by the hydrolysis of the Ammonium

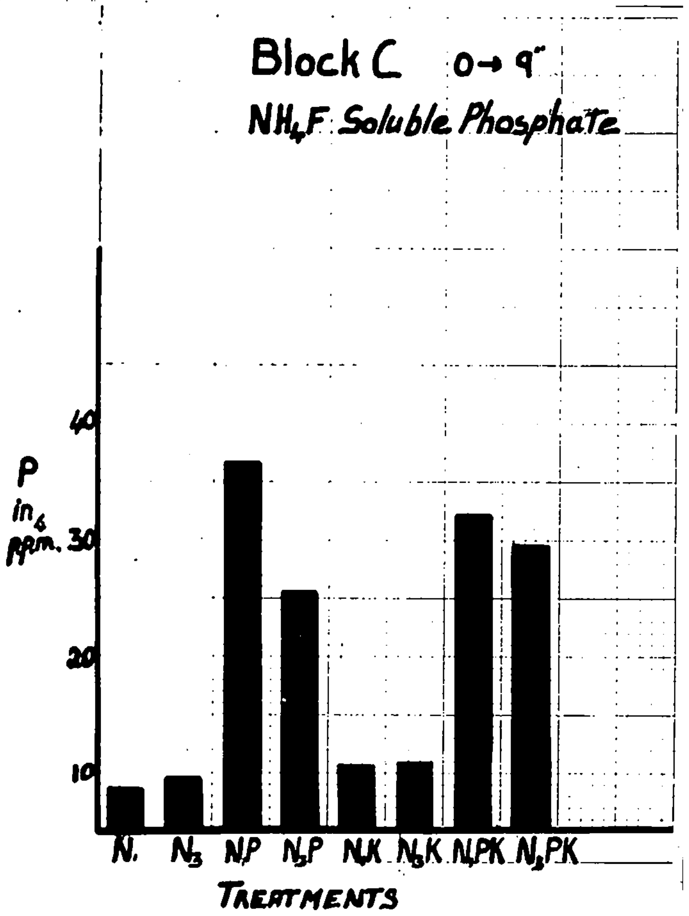
sulphate/.....

FIGURE 25.



A theoretical relationship between the pH and the $pH_2PO_4^-$ in presence of given amounts of Fe^{3+} and Al^{3+}. Filled circles, experimental data from a Scottish soil. (22)

FIGURE 26.



sulphate with the formation of sulphuric acid.

A possibility consequent to increased acidity is revealed by the work of Ericksson (28). Using the p value (negative log of the ionic activity) for the $H_2PO_4^-$ Fe^{+++} and Al^{+++} he deduces formulas for the relationship between ions and their molecules dependent on the pH of the medium. Fig. 25 reproduces the graph drawn up by him showing the $pH_2PO_4^-$ relative to pH in a given concentration of Fe^{+++} and Al^{+++}. From this we see that at a pH of 2 there is a relatively low pH_2PO_4 (that is to say a high concentration of H_2PO_4) which increases as the pH increases to a pH of 3 and then again decreases as the pH increases to 3.8. At a pH of 4.5 the concentration of H_2PO_4 reaches an absolute minimum, PH_2PO_4 7.5.

Assuming that the ammonium sulphate can induce a temporary drop in pH to as low as 3.8 the concentration of $H_2PO_4^-$ in solution would be in the vicinity of .5 p.p.m. and could thus account for the losses involved.

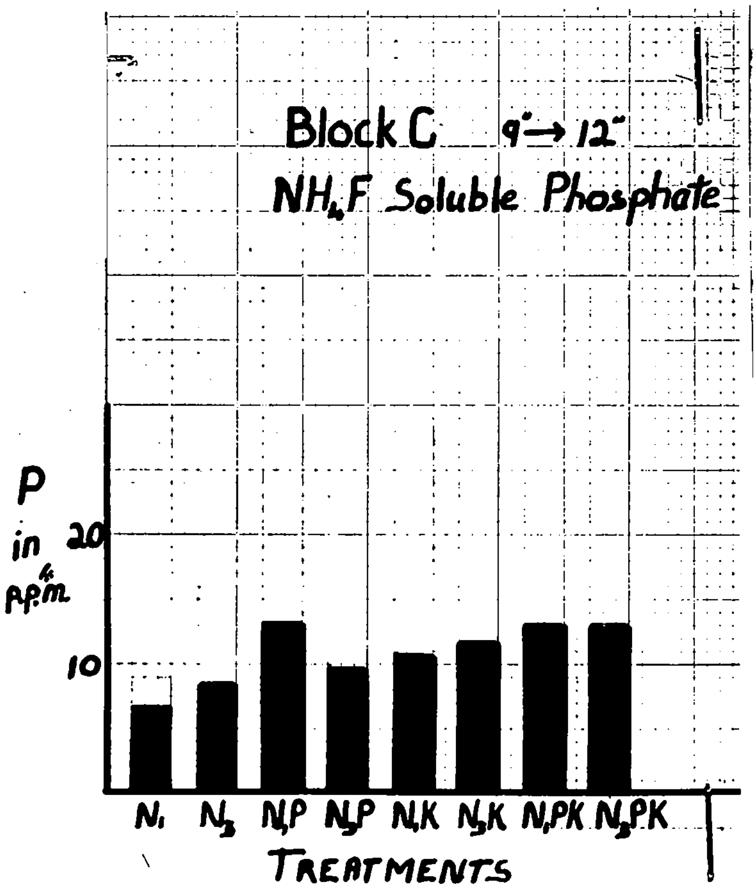
Figure 26 giving a graph of the NH_4F - HCI soluble P in 0" - 9" of soil illustrates the findings. The values represent the total for four plots and divided by four will give the average for each treatment. Those plots receiving Phosphate stand out above all the other with the N_1P plots the highest, followed by the N_1PK, N_3PK and N_3P treatments in that order.

<u>9" - 12"</u>.

In this layer of soil there is only 5% significant difference between the respective treatments. The tendency is seen to be due to the fact that where Phosphate is added there is more of the NH_4F - HCI soluble P in this layer and that this applies more especially on those plots where no Nitrogen was given (as is the case with Citric Acid Soluble Phosphate). Here is also an indication that where Potash is applied there is an

increase/.....

FIGURE 27.


Block C 9" → 12"
NH4F Soluble Phosphate
P in p.p.m.
20
10
N1
N3
N1P
N3P
N1K
N3K
N1PK
N3PK
TREATMENTS

increase in the NH_4F - HCl soluble P of this layer, irrespective of whether Phosphate was applied or not (Table 36) The results are given also on Fig. 27 where graphs of treatment totals are given, illustrating the statistical findings.

Investigation of the lower depths of the subsoil reveals no further differences and when all the depths following the initial 9" are put together there is also nothing of significance as is the case with Citric acid Soluble Phosphate. The N_1 plots show the same tendencies as those revealed in the survey of the Citric acid soluble Phosphate. Tables 37, 38 and 39.

If one totals the plots receiving P and compares them with those receiving no P then the subsoil of the former appears slightly richer than that of the latter. (Table 39). However not much weight can be given to this as the difference is small and the soils extremely heterogeneous although these results do appear to be less variable and more consequent to the treatments than the citric acid values.

<u>Block B</u> (Irrigated).

0" - 9".

The significant differences shown on Table 40 are due to applications of Super Phosphate which increase the NH_4F soluble Phosphate fraction of this layer to a highly significant degree. There is in addition a tendency (not statistically significant) for applications of Nitrogen to minimise this increase. Where the two elements Nitrogen and P are applied together, the P accumulation in this layer is not as great as when P is applied alone. Where Nitrogen only is applied the NH_4F soluble P of this layer is not significantly diminished relative to those receiving neither N nor P.

An investigation of the layers 9 - 12", 12 - 15"

and/....

TABLE 35.

BLOCK C.

NH_4F SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

0 - 9" of soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Sub Block I	11.0	15.0	76.0	50.0	21.0	27.0	74.0	66.0	340.0
II	27.0	21.0	56.0	36.0	21.0	36.0	50.0	56.0	303.0
III	23.0	23.0	104.0	96.0	28.0	25.0	83.0	104.0	486.0
IV	28.0	37.0	130.0	72.0	35.0	21.0	114.0	72.0	509.0
	89.0	96.0	366.0	254.0	105.0	109.0	321.0	298.0	1638.0

$F = 38.11^{**}$

NP

	N_1	N_3	Total
-P	194.0	205.0	399.0
+P	687.0	552.0	1239.0
Total	881.0	757.0	1638.0

F for N = 5.41^{*}
F for P = 24.7^{**}
F for NP = 7.5^{*}

NK

	N_1	N_3	Total.
-K	455.0	350.0	805.0
+K	426.0	407.0	833.0
Total	881.0	757.0	1638.0

F for K = < 1
F for NK = 2.58 not sig.

PK

	-P	+P	Total.
-K	185.0	620.0	805.0
+K	214.0	619.0	833.0
Total	399.0	1239.0	1638.0

F for PK = < 1

TABLE 36.

BLOCK C.

NH_4F SOLUBLE PHOSPHATE IN ppm.
9 - 12" of soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
Sub Block I	4.0	12.0	33.0	17.0	21.0	27.0	28.0	33.0
II	17.0	20.0	17.0	13.0	9.0	26.0	21.0	21.0
III	19.0	21.0	39.0	29.0	38.0	26.0	36.0	36.0
IV	28.0	29.0	41.0	37.0	39.0	38.0	44.0	37.0
	68.0	82.0	130.0	96.0	107.0	117.0	129.0	127.0

	Total
Sub Block I	175.0
II	144.0
III	244.0
IV	293.0
	856.0

$F = 3.46^{*}$

NP

	N_1	N_3	Total
-P	175.0	199.0	374.0
+P	259.0	223.0	482.0
	434.0	422.0	856.0

F for N = <1
F for P = 9.36^{**}
F for NP = 2.85 not significant

NK

	N_1	N_3	Total
-K	198.0	178.0	376.0
+K	236.0	244.0	480.0
	434.0	422.0	856.0

F for K = 8.67^{**}
F for NK = <1

PK

	-P	+P	Total
-K	150.0	226.0	376.0
+K	224.0	256.0	480.0
	374.0	482.0	856.0

F for PK = 1.54 not sig.

TABLE 39.

BLOCK C.

NH_4F SOLUBLE PHOSPHATE IN ppm.

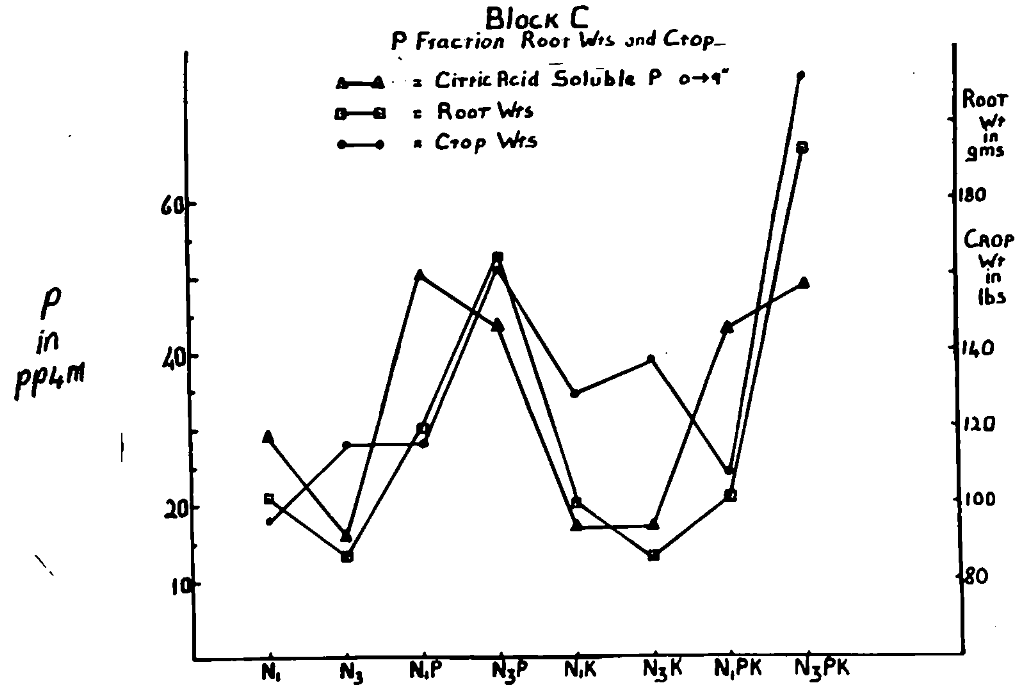
SUM OF 9" - 18" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total.
Sub block I	11.0	33.0	74.0	45.0	53.0	52.0	63.0	57.0	388.0
II	40.0	49.0	31.0	28.0	21.0	63.0	42.0	37.0	311.0
III	57.0	62.0	82.0	86.0	88.0	61.0	97.0	99.0	632.0
IV	54.0	110.0	90.0	92.0	88.0	60.0	92.0	96.0	682.0
TOTAL	162.0	254.0	277.0	251.0	250.0	236.0	294.0	289.0	2013.0

Not significant

+P	-P
1111.0	902.0

FIGURE 28.


Block C
P Fraction Root Wts and Crop
= Citric Acid Soluble P 0→9"
= Root Wts
= Crop Wts
P
in
ppm
60
40
20
10
Root
Wt
in
gms
180
Crop
Wt
in
lbs
140
120
100
80
N1
N3
N1P
N3P
N1K
N3K
N1PK
N3PK

and 15 - 18", collectively and individually adds no further definite information (Tables 41, 42, 43, and 44). It would thus appear, that under irrigation the movement or uptake of P is more or less uniform on all plots with the exception of the N_3PK and N_3P plots where the movement or uptake is greater. The uniform and relatively deep root system found on this Block (Ch. III) can be taken as another reflection of the effects of the postulated movement of P.

Indirectly the role of K in increasing the availability of P can be assessed from the N_3K plots. Here, despite the absence of abundant, available or exchangeable P a large root system and good crop is produced. (See end of Chapter).

In order to determine whether there is any correlation between root development or crop production and the P determined in this investigation figures 28 and 29 were drawn up.

They give the graph of the Phosphate extracted in the top 9" of soil expressed in p.p.m. against the root weight in gms. and the weight of 1st and 2nd grade grapes in lbs.

<u>Block C</u> (unirrigated).

Figure 28 gives the graph for this Block. The correlation is reasonably good between the root system and the Citric acid Soluble Phosphate. Bearing in mind that Nitrogen plays the chief role in determining the crop the correlation between this fraction of the Phosphate and the crop is also reasonable. NH_4F extracts proportional amounts of phosphate from the soil (figure 33) and thus the figures show the same tendancies as those of citric acid. Tables 24, 35, 30 and 40. For this reason the graph is not also included on Figure 28.

On the N_1 plots both roots and citric acid Soluble P are high while the crop is relatively low.

The/

TABLE 40.

BLOCK B.

NH_4F SOLUBLE PHOSPHATE EXPRESSED AS P IN ppm.

0 - 9" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
Sub block I	33.0	32.0	89.0	77.0	27.0	38.0	43.0	73.0
II	32.0	18.0	120.0	63.0	16.0	24.0	93.0	45.0
III	12.0	10.0	83.0	38.0	14.0	14.0	67.0	74.0
IV	29.0	29.0	38.0	77.0	21.0	19.0	83.0	72.0
V	21.0	30.0	74.0	40.0	23.0	38.0	126.0	38.0
VI	35.0	40.0	101.0	120.0	40.0	52.0	107.0	101.0
TOTAL	162.0	159.0	505.0	415.0	141.0	185.0	519.0	403.0

	Total.
Sub block I	422.0
II	411.0
III	312.0
IV	378.0
V	370.0
VI	596.0
TOTAL	2489.0

$F = 11.44^{**}$

NP	N_1	N_3	Total.
-P	303.0	344.0	647.0
+P	1024.0	818.0	1842.0
	1327.0	1162.0	2489.0

F for N = 143 not sig.
F for P = 75.3^{**}
F for NP= 3.38 not sig.

	N_1	N_3	Total.
-K	667.0	574.0	1241.0
+K	660.0	588.0	1248.0
Total	1327.0	1162.0	2489.0

F for K = LI <1
F for NK= LI <1

	-P	+P	Total
-K	321.0	920.0	1241.0
+K	326.0	922.0	1248.0
Total	647.0	1842.0	2489.0

F for PK = LI <1

TABLE 41.

BLOCK B.

NH_4F SOLUBLE P [illegible].

9" - 12" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
[illegible] BLOCK I	24.0	29.0	21.0	2[illegible].0	19.0	29.0	29.0	2[illegible].0
II	25.0	14.0	33.0	22.0	12.0	19.0	10.0	13.0
III	7.0	3.0	32.0	24.0	19.0	10.0	12.0	20.0
IV	25.0	32.0	23.0	12.0	12.0	21.0	23.0	3[illegible].0
V	19.0	21.0	17.0	19.0	7.0	21.0	21.0	7.0
VI	21.0	20.0	18.0	34.0	36.0	30.0	23.0	1[illegible].0
TOTAL	121.0	119.0	144.0	139.0	105.0	130.0	11[illegible].0	1[illegible].0

	TOTAL.
[illegible] BLOCK I	207.0
II	148.0
III	135.0
IV	186.0
V	132.0
VI	190.0
TOTAL	1006.0

F = [illegible] < 1

TABLE 42.

BLOCK B.

NH_4F SOLUBLE P [illegible].

(12" - 15" of soil).

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$
[illegible] BLOCK I	27.0	30.0	15.0	25.0	21.0	25.0	27.0
II	19.0	13.0	32.0	17.0	11.0	19.0	7.0
III	8.0	3.0	28.0	25.0	8.0	7.0	8.0
IV	24.0	41.0	18.0	11.0	13.0	21.0	21.0
V	16.0	22.0	15.0	38.0	6.0	18.0	26.0
VI	23.0	19.0	21.0	35.0	32.0	32.0	19.0
TREATMENT TOTALS	117.0	128.0	129.0	1[illegible]3.0	91.0	123.0	103.0

[illegible] BLOCK I	$N_3P_2K_2$	Block Total.
I	28.0	200.0
II	12.0	130.0
III	26.0	114.0
IV	15.0	174.0
V	16.6	147.0
VI	10.0	191.0
[illegible] TOTAL	107.0	956.0

Not Significant.

TABLE 43.

BLOCK B.

NH_4F SOLUBLE P IN ppm.

15" - 18" OF SOIL.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$
SUB BLOCK I	30.0	27.0	14.0	23.0	19.0	23.0	16.0	29.0
II	12.0	14.0	23.0	28.0	9.0	17.0	5.0	11.0
III	7.0	22.0	28.0	24.0	14.0	26.0	8.0	26.0
IV	18.0	28.0	15.0	20.0	12.0	25.0	14.0	23.0
V	15.0	22.0	17.0	14.0	10.0	22.0	23.0	28.0
VI	19.0	18.0	18.0	21.0	27.0	22.0	18.0	28.0
TREATMENT TOTAL	101.0	131.0	115.0	130.0	82.0	135.0	84.0	145.0

	BLOCK TOTAL.
SUB BLOCK I	181.0
II	109.0
III	115.0
IV	175.0
V	122.0
VI	221.0
TOTAL.	923.0

Not Significant.

TABLE 44.

BLOCK B.

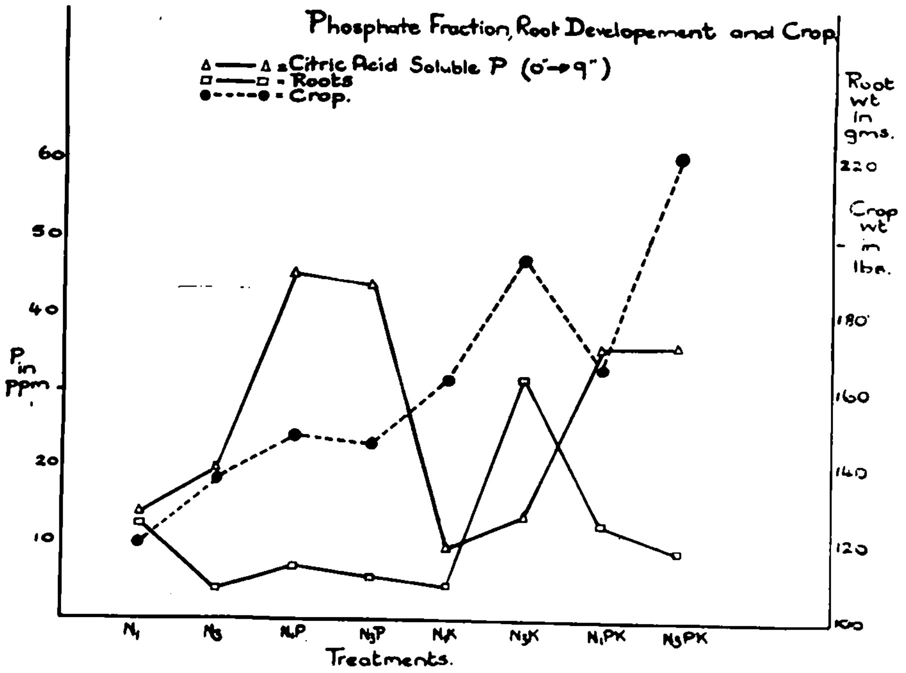
NH_4F SOLUBLE P ppm. (Total of 9" - 18" of Soil).

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$
Sub Block I	81.0	86.0	50.0	77.0	59.0	78.0	72.0	85.0
II	56.0	41.0	88.0	57.0	32.0	55.0	37.0	36.0
III	22.0	28.0	88.0	74.0	41.0	23.0	28.0	80.0
IV	67.0	101.0	56.0	33.0	37.0	77.0	60.0	86.0
V	50.0	65.0	49.0	71.0	24.0	61.0	70.0	21.0
VI	63.0	57.0	56.0	110.0	75.0	94.0	60.0	44.0
Treatment Totals	339.0	378.0	387.0	422.0	278.0	388.0	327.0	352.0

	Block Total.
Sub Block I	588.0
II	402.0
III	364.0
IV	537.0
V	401.0
VI	579.0
Treatment Total	2871.0

Not Significant P = <1

Block B


Phosphate Fraction, Root Developement and Crop
Citric Acid Soluble P (0"→9")
Roots
Crop.
P in ppm
60
50
40
20
10
Root wt in gms.
220
Crop wt in lbs.
180
160
140
120
100
N1
N3
N1P
N3P
N1K
N3K
N1PK
N3PK
Treatments.

The former two drop on the N_3 plot but the crop increases. On the N_1P plots both roots and P increase sharply while the crop remains steady despite the deficiency in Nitrogen. On the N_3P plots the crop of course increases sharply as does the root system while the Citric acid Soluble P drops slightly. On the N_1K all drop but the crop less than the other two. On the N_3K roots drop very slightly, the Citric Acid Soluble P remains steady while the crop increases. The crop on the N_1PK plots is very low but both the root weights and the Phosphate increase. On the N_3PK plots all three climb to a high value. Thus as a means of assessing direct soil potential with regard to Phosphate, citric acid would appear to be a good extracting agent. However it is also obvious that the vines are able to make use of a far larger fraction of Phosphate than is revealed. The N_3K plots produce the third highest crop despite the deficiency of Citric Acid Soluble Phosphate.

For this reason the NH_4F-HCl extraction which removes a larger fraction of soil phosphate would bear further investigation as a means of assessing soil fertility relative to vines and other deciduous crops.

On Block B (Figure 29) there is very little or no correlation between either Phosphate fractions and the root development and crop production. The greatest crop is produced on a plot with a relatively large amount of Citric Acid Soluble P present, by no means the greatest, while the second greatest crop is produced on a plot having one of the lowest values for Citric Acid Soluble Phosphate.

Although the possibility of establishing a critical figure for Citric Acid Soluble P for vines grown under dryland conditions exists, the Phosphate that the vine is able to remove from the soil under irrigation is so great that it makes the citric acid data virtually useless.

The/.....

The values for Citric Acid Soluble P extracted from the lower layers are virtually the same and thus there is little point in using them as a criterion of fertilization requirement.

One point remains obvious and that is that the other fertilizers such as Nitrogen, Potash, and trace elements can be raised considerably before Phosphate will become a limiting factor in production of a crop on export vines under irrigation.

Both in Chapters V and VI mention is made of the fact that indications are found of an influence of Potash on the Phosphate status of the soil. (Tables 24, 26, 35 and 36). In most cases these results must be ascribed to the soil heterogeneity. There are, however, those results which are statistically significant and added to this is the persistance with which the indications are found. For these reasons a closer investigation of the effects of Potash on Phosphate is warrented.

Lewis Jordan and Juve (3) as well as Overstreet and Dean (31) studied the effects of cations on the availability of soil Phosphate. The former group studied the effects of sodium and found that it increased the availability of both applied and naturally occurring Phosphate. The latter group studied Potash and found a similar effect.

As phosphate feeding takes place from the liquid and not from the solid phase it follows that increased availability must imply increased mobility or potential mobility. There is also the fact that all indications of loss from the top soil are accompanied by indications of increased Phosphate in the lower soils where Potash is concerned.

The/.....

The effect of increased availability of Phosphate where Potash is applied is well illustrated by Tables 55 and 58. Table 23 shows that leaf petioles show more P on the N_3K than on the N_3 plots on Block B. On Block C the N_3K plots have more P than even the N_3P plots.

In table 58 it is seen that on Block C the total plant phosphate shows the same tendencies as found in the leaf petiole analysis (table 23) in that the N_3P is higher than the N_3K but the latter showing a greater total than the N_3 plots. In addition to this the N_3PK plots show that here the total plant P reaches the highest value even though the % P is not the greatest as shown in table 23. Thus here is additional proof of the fact that K increases the availability of the P.

The total economy of Block B was not studied but it is apparent from the leaf petiole values that here, as shown above, Potash plays an even greater role in increasing the availability of naturally occurring P.

NITROGEN.

Tables 45 - 49 give the results obtained from a determination of the total Nitrogen on the soils of the B and C blocks.[x] As can be seen there is little variation on either of the Blocks, due either to the applications of fertiliser or to inherent differences in the soils themselves. The usual process of humus decomposition has occurred on these soils, which, once having reached a low level maintains the little organic material left. Additions of Ammonium Sulphate, due to its extreme mobility can in no way increase the reserves in the soil. This loss of organic matter is of great importance not only for the deficiency of Nitrogen it entails, but due to other deficiencies such as loss of exchange capacity and other effects some of which are by no means clearly understood. It is clear that any fertilization program relying on artificial/....

x See Appendix.

artificial fertilizers alone must fail in the long run, unless provision is made to supplement the Nitrogen reserve on what amounts to the organic matter in the soil.

The fact that applications of Ammonium Sulphate result in the acidification of a soil, is well known and earlier studies on these plots showed a greater acidification on those plots which had received applications of Nitrogen (15). The 1954 survey as shown in Tables 50 - 55[x] shows no statistical differences between the pH's derived from the respective treatments, irrespective of nitrogen application.

It is my opinion that this ties up with the retrogression of organic matter in the soil and the consequent loss of exchange capacity. The soils receiving Ammonium Sulphate become acid at a greater rate and soon reached a level where further acidification only occurs at a very slow rate. The result being that the slower acidification on the other soils consequent to the loss of organic material and hence exchange capacity, together with the leaching out of the bases from the soils, has been able to reach the same low level although over a longer period of time.

Another factor in assessing the effect of Ammonium Sulphate on soil pH is the time of sampling. Fourie (32) studied the Nitrification of Ammonium Sulphate in soils and finds that the acidifying effect of this fertilizer is greatest in Spring and Autumn. Thus Piaget's (15) samples taken in spring would show greater differences than those of this survey taken in Winter.

The fact that Piaget (15) could find no greater loss of Ca on those soils receiving dressings of $(NH_4)_2 SO_4$ would then mean, as he stated that the absolute low for the Ca content of the soil had already been reached on all the soils.

x See Appendix.

Summary/....

Summary:

On Block C additions of Supers increase the amounts of this NH_4F -HCl soluble fraction of P significantly in the top 9" of soil. Additions of 800 lbs. Ammonium Sulphate result in a decrease in the P of this layer and also shows a negative interaction with the applied supers. In other words where the two are added together there is less P in this layer than when P is added alone.

In the following layer of soil 9 - 12" the plots receiving P are significantly richer than the others and this applies more especially where no Nitrogen was added. This latter is similar to what was found with the citric acid extraction.

There is an indication that those plots receiving dressings of K are richer in P than the other plots. The lower layers show no statistically significant differences.

On Block B only the initial 0 - 9" of soil shows any significant differences. These differences are due to the fact that where P was applied the plots give a significantly greater P extraction with NH_4F-HCl solution. The effects of Nitrogen and its interaction with P are on this block only indications and are not statistically significant as on Block C.

Lower depths show no statistically significant differences.

These results confirm those found with the citric acid extract and lend weight to the theory of P mobilization by Ammonium Sulphate on this soil. At present however the stronger growth rate of the plots receiving the higher N plus P is a more feasable explanation for the loss of P.

The total Nitrogen content and pH of the soils show no significant differences due to differences in fertilization practise.

CHAPTER VII.

THE PHOSPHATE ECONOMY OF BLOCK C.

In the preceding two chapters effects were postulated for Nitrogen and Potash on the Phosphate status of the soil. It was suggested that where Nitrogen is applied it results in a movement of Phosphate into the sandy soils of the Bien Donne Vineyard Fertilisation Experiment. No direct proof of this movement could be found and thus it was decided to study the entire P economy of Block C in the hope that more definite proof could be obtained of such movement. Where Potash is concerned a reasonably strong case was made for its ability to increase the availability of P in the soil, however it is only from a study of the total P economy that this can either be proved or disproved.

Involved in this economy of the Phosphate are the amounts removed by the crop and pruned shoots, the amount bound in the main roots and the body of the vine and the total amount of Phosphate present in the soil at the time of the investigation. The total amount of Phosphate added to the soil is also of importance. Table (58) was thus drawn up giving the necessary data.

Firstly the total weight of shoots pruned of each plot (Barlinka vines only) was obtained from the records (8) for the entire duration of the experiment. Samples of these shoots taken in 1953 were analysed in the same year for P average percentages obtained for each treatment. From these figures it was possible to determine the total P removed in the prunings. The crop was treated in similar manner during 1954 but had first to be split into three fractions; berries, pips and bunch stalks. The composition of the crop with regard to these three constituent elements was obtained on an average samples for each of the treatments on Block C. In Order to determine the P bound in the mature plant one vine from each plot was removed in 1955 together with its larger roots in a block extending 2½ feet from the stem of the vine.

VINE PHOSPHATE ECONOMY ON BLOCK C.

A. PHOSPHATE IN SHOOTS PRUNED OFF AND REMOVED EACH YEAR:

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	
1. PIN SHOOTS.									
Weight of Shoots. Wet in Kgm.	592.8	745.1	591.7	870.3	585.6	710.3	583.4	917.6	
Weight of dry Shoots 60% moisture	237.12	298.04	236.68	348.12	234.24	284.12	233.36	367.64	
% Pinshoots on dry weight.	.038%	.038%	.035%	.039%	.038%	.036%	.041%	.038%	
W.t of P removed	90.11 gms.	113.2 gms.	82.84 gms.	142.80 gms.	89.01 gms.	98.07 gms.	102.34 gms.	139.48 gms.	
2. PIN CROP.									
Weight of crop in Kgm.	2739.7 Kgm.	2876.7 Kgm.	2815.7 Kgm.	3588.1 Kgm.	2935.9 Kgm.	3150.2	2774.6	3875.0	
(a) Weight of bunch Stalks. 2.04% of crop.	55.89 Kgm.	58.65 Kgm.	57.44 Kgm.	73.20 Kgm.	59.90 Kgm.	64.26	56.60	79.05	
Dry wt. (65% moisture)	19.56 Kgm.	20.53 Kgm.	20.10 Kgm.	25.62 Kgm.	20.96 Kgm.	22.49	19.81	27.67	
% P in dry Stalks.	.126%	.138%	.142%	.304%	.268%	.238%	.328%	.140%	
gms. P removed.	24.65 gms.	28.55 gms.	28.34 gms.	77.89 gms.	56.19 gms.	53.53 gms.	64.98 gms.	38.73 gms.	
(b) Weight of Pips 1.36% of crop.	37.26 Kgm.	39.12	38.29	48.80	39.93	42.84	37.74	52.70	
% P in pips dry wt.	.305	.300	.350	.3000	.297	.285	.305	.285	
Dry Wt. of pips 20% Moisture	29.81 Kgm.	31.29 Kgm.	30.63	39.04	31.94	34.27	30.19	42.16	
gms. P removed.	90;92	93.87	107.20	117.12	94.86	97.67	92.1	120.2	
(c) Wt. of Berries Kgm.	2646.55	2778.90	2719.97	3466.1	2836.07	3043.10	2660.26	3744.25	
% P in berries wet wt.	.017%	.018%	.018%	.018%	.019%	.019%	.021%	.017%	
gms. P removed.	449.91 gms.	500.20 gms.	489.60 gms.	623.90 gms.	538.85 gms.	578.19 gms.	558.65 gms.	636.52 gms.	
Wt. of P Present in Vines:									
Upper Portion.									
Wet weight in Kgm.	694.4	694.4	716.8	761.6	643.2	768.0	560.0	892.8	
Dry weight (60% moisture)	277.8	277.8	286.7	304.6	257.3	307.2	224.0	337.1	
% P	.038	.038	.035	.039	.038	.038	.041	.038	
Weight P in gm.	105.6	105.6	100.4	118.8	97.8	116.7	91.8	128.1	
ROOTS:									
Wet weight in Kgm.	310.4	345.6	288.8	316.8	281.6	292.4	294.4	371.2	
Dry weight (60% moisture)	124.2	138.2	115.5	126.7	112.6	117.0	117.8	148.5	
% Phosphate	.124	.106	.152	.135	.104	.109	.150	.140	
Weight P in gm.	154.0	146.4	175.6	171.1	117.1	127.5	176.7	207.9	
TOTAL PLANT P.	915.3	987.8	984.0	1251.6	993.8	1071.7	1086.6	1619.2	(Fig.26)
WEIGHT OF PIN SOIL.									
% P in soil top 9"	.0179	.0175	.0247	.0185	.0174	.0183	.0191	.0184	
Weight top 9" soil on plot (gm.)		38,400,000.							
Weight P	6873.0	6720.0	9485.0	7104.0	6682.	7007.2	7334.0	7066.0	
% P in soil 9" - 12"	.0134	.0152	.0157	.0146	.0148	.0143	.0132	.0131	
Weight of 9 - 12"		12,800,000.							
Weight P.	1715.0	1946.0	2010.	1869.8	1894.0	1630.5	1690.0	1677.0	
TOTAL P in SOIL TOP 12"	8589.0	8666.0	11495.0	8973.0	8576.0	9523.0	9024.0	8743.0	(Fig.27)

"Original" P in top 12" = total P in soil + Plant P - Added P.	9504.3	9653.8	12479.0 2704.5	10224.6 2704.5	9569.8	9909.0	10110.6 2704.5	10362.2 2704.5	
	9504.3	9653.8	9774.5	7520.1	9569.8	9909.0	7406.1	7657.7	(Fig. 28)

Phosphate expressed as P.

1. Weight of P added to each P lot 1939 - 1953.

26.83 lbs. P

= 12170.08 gms. P of which 4/9 is on Expt. Vines.

= 5408.92 gms. P on Experimental Vines.

= 2704.46 gms. P on Barlinka Expt. Vines.

From the analysis of the respective portions Root samples were analised during 1954, the total P involved could be determined. For the total P left in the soil a 22% HCl extract (1) was made of the top 12" and the Phosphate determined according to the method proposed by Wilson (33).

All this abovementioned Phosphate was then totalled and, where appropriate, the total P, added as Super Phosphate during the duration of the experiment, was subtracted.

The answer should then be theoretically, the total P status of the top 12" of soil at the time of commencement of the experiment. It will also include the Phosphate which the plant has obtained from the lower layers of the soil but there is no means of correcting for this error.

Before examining the end results of the table (58) there are one or two points raised in the body of the table which deserve mention.

If one examines the gross weight of each portion of the plant then it is clear that the smallest plant weight usually occurs on the N_1PK treatment while the percentage P in these plants is usually the highest. This serves as further proof of the effect of K on the availability of P. The N_1P plots, having exactly the same weight of P added as the N_1PK plots, show a smaller percentage of P and a smaller total weight of P in the plant material despite the fact that the weight of the plant material is usually greater than on the N_1PK plots. A further illustration of this is the fact that the gross P in the plant material is almost as great on the N_3K plots where no P was added as it is on the N_3P plots.

The results are grouped as shown in Table 59 and now the effects of the respective treatments can be more easily seen. From this it seems that the applications of Nitrogen result in an increase of the total Phosphate in the plant by as much as two applications of Phosphate and that the greatest increase is where the two are applied together.

Further/.....

ORIGINAL P IN TOP 12" OF SOIL. - TABLE 60.

	+P	-P	Total.
+K	15063.8	19478.8	34542.6
-K	17294.6	19157.1	36452.7
TOTAL	32358.4	38636.9	70995.3

	N_1	N_3	Total.
+P	17180.6	15177.8	32358.4
-P	19074.1	19562.8	38636.9
TOTAL	36254.7	34740.6	70995.3

	N_1	N_3	Total.
+K	16975.9	17566.7	34542.6
-K	19278.8	17173.9	36452.7
TOTAL	36254.7	34740.6	70995.3

TOTAL PLANT P. TABLE 59

	N_1	N_3	Total.
+P	2070.6	2870.8	4941.4
-P	1909.1	2059.5	3968.6
TOTAL	3979.7	4930.3	8910.0

	N_1	N_3	Total.
+K	2080.4	2690.9	4771.3
-K	1899.3	2239.4	4138.7
TOTAL	3979.7	4930.3	8910.0

	+P	-P	Total.
+K	2705.8	2065.5	4771.3
-K	2235.6	1903.1	4138.7
TOTAL	4941.4	3968.6	8910.0

Further it is obvious that there is an interaction between Nitrogen and Potash as well as between Potash and Phosphate. The order of interaction being NP, PK, NK on the uptake of Phosphate.

As in the case of Nitrogen and P the individual action of Potash on the gross P present in the plant is small being even smaller than the individual action of Nitrogen. The individual action of Phosphate is only slightly greater than that of Nitrogen.

Additions of P account for an increase of 972.8 gms. P Potash 632.6 gms. P, and Nitrogen 950.6 gms. P over those plots where they are not applied.

These figures must not be taken as precise, but rather as indicative since in a survey such as that laid out on table 58 there are numerous unavoidable sources of error. When the P from the vines and that in the top 12" of soil is totalled for each treatment and the Phosphate, added as superphosphate, is subtracted, where appropriate, the figures present an entirely different picture.

The case is now that those plots which have had dressings of P appear to have less P than those which had no dressings of P. Grouping the results as shown on table 60 makes for easier interpretation of the differences.

Where P has been added there is less P left in the top 12" of soil than on those plots where no P was added and the effect of 'loss" is more pronounced on those plots receiving dressings of Nitrogen. There is thus a positive interaction between Nitrogen and Phosphate. Additions of Nitrogen alone do not result in any appreciable "losses".

The same holds good for Potash and its effect on the Phosphate status of the soil. Again there is a positive interaction between additions of P and K while additions of K alone do not result in any great loss.

N and K show a negative interaction in that where K is aplied in the absence of Nitrogen there is a greater

loss/...

loss of P than when Potash is applied in the presence of Nitrogen.

Here again the effects of the interactions seem to be greater than the effects of the individual actions.

At first glance these results are rather disconcerting but they only reflect what has been pointed out in previous Chapters, that is, that there is a 'loss' of P from the top soil where Nitrogen is applied and that this is more especially so on those plots where supers was also added.

In the earlier chapters this was ascribed to a leaching effect, but one result in this table points to another possibility which, on closer examination would seem to be an important one. The result referred to is the loss of P on the N_1PK plots. As has been seen the % P in the plant material of these plots is high and from Chapter III it is apparent that here one has to do with a plant which is dying and has already lost a large portion of its root system. (They were the only plots where the root system showed no positive response to P fertilisation and it was deduced that this was due to the dying back of the vines). Any loss of roots would mean a loss of Phosphate out of the top soil. This P would then be mineralized in the subsoil after a few years but will not easily be detected in soil samples because of the fact that it is localised. Thus in this case the movement must be accounted for biologically rather than as a direct leaching effect. This biological loss could easily account for all the P lost on the N_1PK plots but in the case of the N_3P and N_3PK plots this is not so probable.

The vines on these N_3P and N_3PK plots are growing relatively strongly and there are no signs of an extensive loss of the root system thus, although their very much

larger/.....

FIGURE 30.

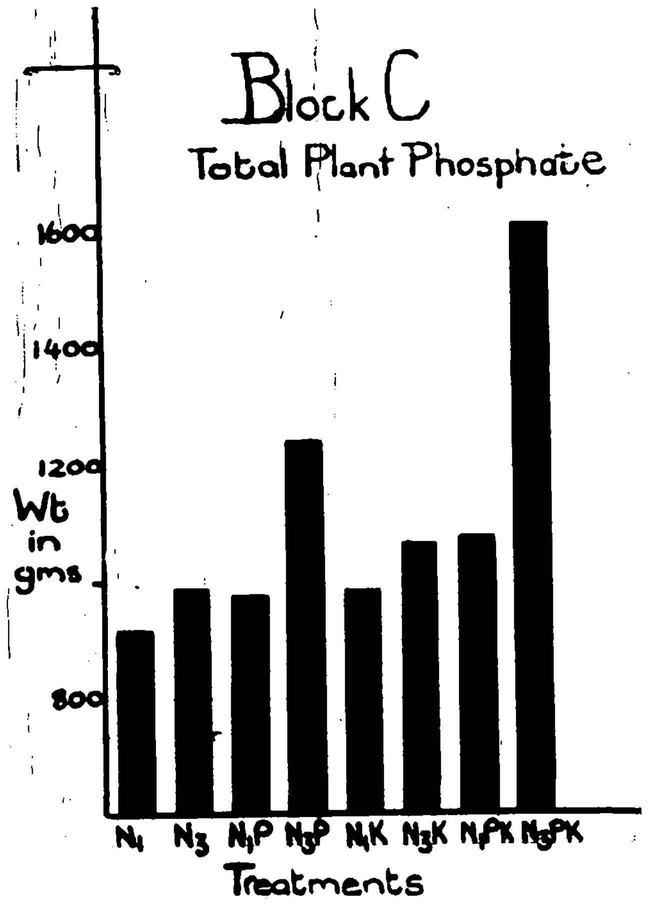


FIGURE 31.

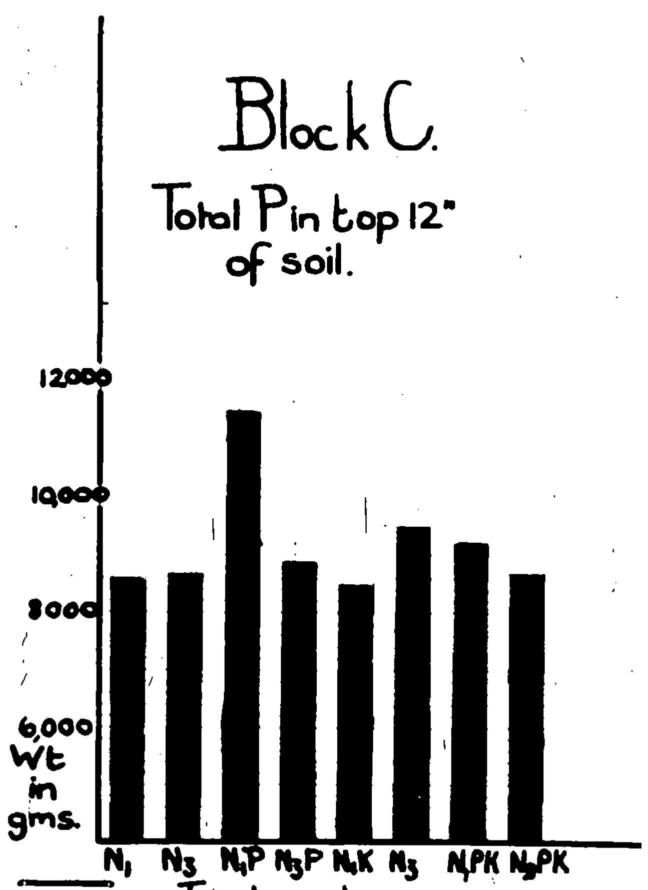


FIGURE 32.

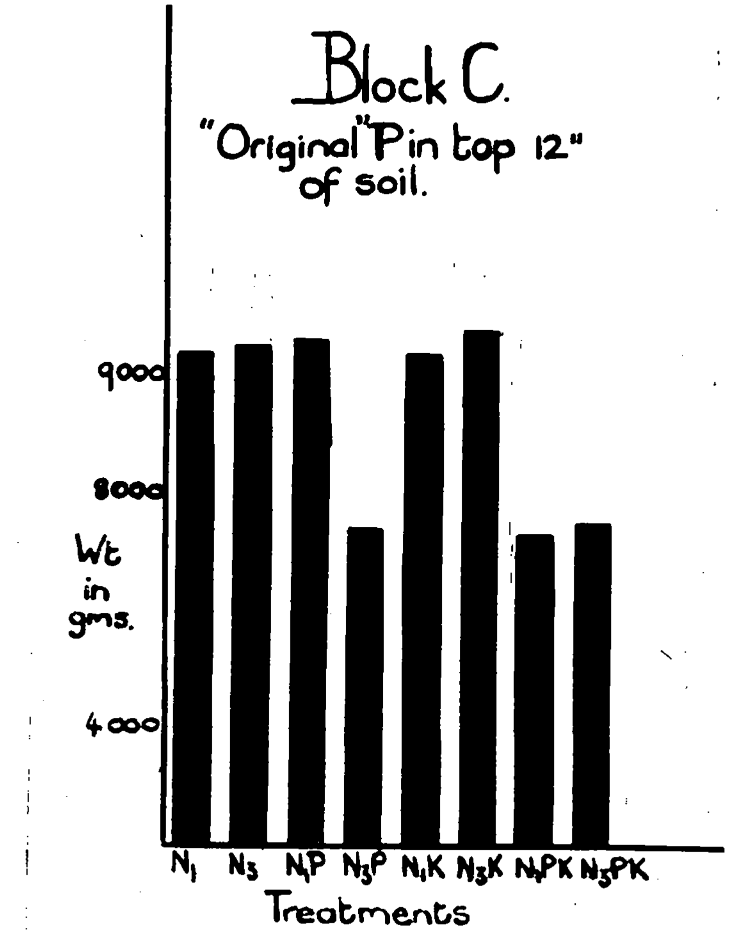
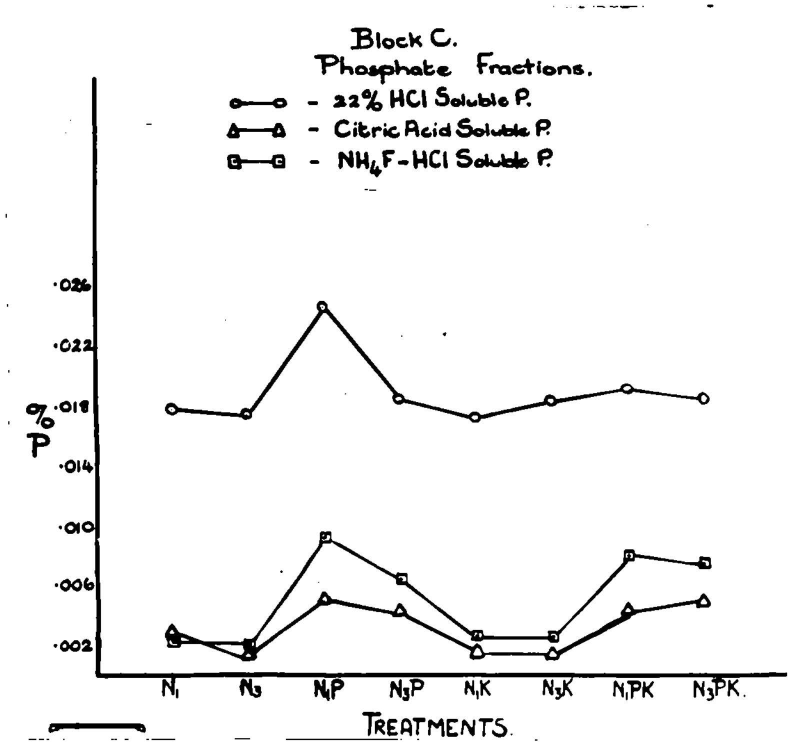


FIGURE 33.



larger root system (Chapter III) would mean that 'normal' loss of fine roots would be far greater than on any other plots, this is not the entire solution to the problem.

As stated in Chapters V and VI there is a movement of P, accelerated by applications of Nitrogen which will account for at least a part of the losses from the top soil on the N_3PK and N_3P plots.

From table 58 it can also be seen that the total P in the top 12" of soil is greater on those plots which have received dressings of Phosphate. The difference is however, not very great. If one considers that in 15 years ± 2700 gms. have been added to an economy that involves 10,000 gms P and more, it is not surprising that these differences are small. In addition to this must be borne in mind the fact of the losses of P from those plots receiving P and the higher rate of Nitrogen. These losses, according to the P economy, amount to ± 2000 gms. Fig. 30, 31, 32 illustrate graphically the findings discussed above.

A statistical interpretation of the 22% HCl soluble P in the top 9" of soil shows no significant difference between the respective treatments, although the N_1P values are considerably higher than the rest. The respective blocks show significant differences, Block IV being the richest - table 61. In 9 - 12" of soil the results are also not significant. Table 62.

Figure 33 gives the graph of these values in the top 9" of soil together with the citric acid and NH_4F-HCl soluble P. The NH_4F-HCl and citric acid graphs show the same tendencies. The former extract however, seems to react more strongly to applications of phosphate. Where no P was applied these results are about the same as for the citric acid solution, but where P was applied they are about twice that of the citric acid. Initially the 22% soluble P graph is the same as the other two. From N_1 a slight drop to N_3

followed/...

TABLE 61.

BLOCK C.

22% HCl SOLUBLE P EXPRESSED AS P IN ppm.

0 - 9" OF SOIL.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$
Sub Block I	174.0	188.3	181.8	204.1	175.1	232.1	133.9	230.2
II	163.3	102.0	229.6	174.0	182.7	199.5	174.4	105.6
III	229.5	193.9	250.2	171.5	168.6	153.6	226.3	178.3
IV	150.3	216.4	327.5	190.1	167.6	147.9	231.1	222.9
TOTAL	717.1	700.6	989.1	739.7	694.0	733.1	765.7	737.0

	Total.
Sub Block I	1519.5
II	1381.1
III	1571.9
IV	1653.8
TOTAL	6076.3

$F = 2.38$ Not Significant.

TABLE 62.

BLOCK C.

22% HCl SOLUBLE P EXPRESSED AS P IN ppm.

9" - 12" OF SOIL.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	$N_1P_2K_2$	$N_3P_2K_2$
Sub Block I	152.00	145.5	176.8	145.5	144.5	146.3	124.6	149.4
II	62.73	116.2	137.0	120.5	138.0	152.0	101.6	94.0
III	186.5	171.0	186.5	136.1	155.2	146.9	148.7	134.0
IV	133.9	176.6	128.0	183.2	154.2	126.8	152.9	145.0
TOTAL	535.13	609.3	628.3	585.3	591.9	572.0	527.8	522.4

	Total.
Sub Block I	1234.6
II	922.03
III	1264.9
IV	1200.6
TOTAL	4572.1

$F = < 1$

followed by a sharp increase to N_1P. From here however the 22% HCl values, although following the same trends, are relative to the N_1values, far lower than are the other two relative to their N_1values.

In other words, from N_1P the 22% HCl values return to the same level as the initial N_1values and although they subsequently show slight increases at the N_1PK and N_3PK values these are small. The 1% citric acid and NH_4F-HCl soluble P on the contrary also decrease from N_1P to N_3P but this latter value is still considerably higher than the N_1 or N_3 values in both cases. The N_1K and N_3K values are as low as the N_1 and N_3 but the N_1PK and N_3PK values are again higher, the NH_4F-HCl extract being again the highest.

SUMMARY OF THE MAIN FACTS DERIVED FROM THE SURVEYS DISCUSSED IN THE PRECEDING CHAPTERS.

The root survey conducted on these plots provided information on the nature of fertilization influences on the root systems of plants, but in addition to this, this survey revealed the value of such root surveys in studying plant growth and development. For example it was known from the crop results (8) that P increased the yields on Block C, but not until the survey was done, was it known that this was at least partly due to the fact that P increased the vines' root system and hence its ability to obtain moisture during the dry periods of the year. Similarly many other facts of basic importance in assessing fertilization influences both on plants and on the P status of the soil were obtained. As this is the first time that a survey of this nature has been conducted in this country and the results found to be of such value, the method has been standardised as set out in an article by J. Vink and A.J. Buys. (34).

The main facts gleaned from the root survey are as follows:

(1) On the irrigated Block B fertilization has no influence on the root development.

(2) Irrigation results in a deeper root system with a more even distribution.

(3) On Block C, phosphate plays a dominant role in determining the root system. It results in considerable increases which are enhanced by applications of Nitrogen.

(4) On roots of diameter less than ½" both phosphate and Nitrogen increase the weights obtained.

(5) The shallowest root system is found on the N_1 plots of this Block followed by the N_1P plots.

(6) In all cases the greatest weight of roots is found in the second foot of soil.

(7) No direct correlation exists between the root system and the uppergrowth of the plant. Separate fertilization factors play the dominant role in determining the root and shoot development.

(8) Shoot development and crop production show a strong correlation.

(9) Irrigation results in a larger crop on what is a relatively small root development, consequently the plants are more sensitive to trace element deficiencies.

In addition to the root survey a chemical analysis of the soil, using two extracting agents, was conducted in order to investigate the Phosphate status. The main points obtained from these surveys are:

(1) Both extracts show significant increases of P in the top 9" of soil on those plots which had dressings of Super phosphate.

(2) The NH_4F-HCl extract "shows a greater P extraction on plots receiving P dressings than the 1% citric acid in this layer.

(3) The former shows a smaller P extract for this layer where Ammonium Sulphate is also applied.

(4) The 1% citric acid extract reveals the N_1 plots as the richest of the non-phosphated plots in the top 9" but one of the poorest in the subsequent layers. Indications of a loss of P on the K plots is also found with a subsequent enrichment of the following 9" - 12" layer.

(5) In the 9" - 12" layer the 1% Citric Acid extract shows a significantly higher value on those plots receiving Phosphate but no Nitrogen.

(6) The NH_4F-HCl extract shows an increase in this layer for all P plots but more especially on those plots receiving P but no Nitrogen.

(7) This latter extract also shows an indication of increased P on those plots which receive dressings of K in this layer of soil.

(8)/.....

(8) The following layers 12" - 15", 15 - 18" show no significant variations for either extract.

(9) All these points apply to the unirrigated Block C. On the irrigated Block B both extracts showed significant differences in the top 9" only.

In order to clarify some of the points raised by these two surveys a total P economy of Block C was undertaken. The main points revealed by this are:-

(i) Where the higher level of Nitrogen is applied, as well as on the N_1PK plots there is a deficit of 2000 gms P in a total economy of $\pm$ 12000 gms P from the top 12" of soil.

(2) Where K is applied there is more P in the plants than where none is added (i.e. more P on the N_3K than the N_3 plots and more on the N_3PK than on the N_3P plots).

All these findings are used to support three main hypotheses. In all cases more work will have to be done before they can be accepted as proven. They are:-

(i) Additions of Potash increase the availability of both applied and naturally occurring P. Of the three this receives the most support in world literature.

(ii) Phosphate is mobile in soils of low adsorptive capacity once these have been saturated with P and this mobility is promoted by the application of Ammonium Sulphate due mainly to the latter's acid nature.

This theory does find a degree of support in world literature but of the three is the most doubtful.

(iii) A plant growing under favourable conditions of moisture and nutrient supply will produce a moderate root system. A lack of two major nutrients, provided they do not occur together, and the other nutrients are in good supply, will result in greatly increased root system. These nutrients are:-

(a) Water, a lack of which results in a course, rambling root system, and

(b)/.....

(b) Phosphate, a lack of which results in a large but finely divided, dense root system. This latter is formulated with the understanding that these influences are secondary to the physical influences exercised by a soil.

APPENDIX.

TABLE 45.

BLOCK C.

NIT[illegible] IN PARTS /100,000.

0" - 12" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	68.4	58.9	42.7	47.0	49.3	49.6	62.7	59.4	438.0
II	53.2	62.8	59.6	66.8	50.9	46.6	52.7	66.8	459.4
III	67.5	51.6	44.8	47.8	35.4	57.4	55.7	46.7	406.9
IV	48.2	55.1	69.1	51.0	48.9	65.8	57.4	51.0	446.5
TOTAL	237.3	228.4	216.2	212.6	184.5	219.4	228.5	223.9	1750.8

Not Significant.

TABLE 46.

BLOCK C.

NITROGEN IN P/100,000.

12" - 24" OF SOIL.

	N_1	N_3	N_1P_2	N_3P_2	N_1K_2	N_3K_2	N_1PK	N_3PK	Total
Block I	62.9	44.3	47.6	42.3	55.1	41.5	57.4	49.7	400.8
II	65.3	55.5	62.5	59.7	57.1	41.5	56.3	75.7	473.6
III	69.1	41.1	45.9	50.4	37.7	44.3	49.3	34.2	372.0
IV	50.4	54.4	63.6	52.6	59.0	38.0	50.5	53.6	422.1
TOTAL	247.7	195.3	219.6	205.0	208.9	165.3	213.5	213.2	1668.5

Not Significant.

- . -

TABLE 49.

BLOCK B.

NITROGEN PP 100,000.

24" - 36" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
Sub Block I	5.9	33.6	40.2	50.5	5.9	28.5	67.3	51.9
II	27.8	23.4	2.9	111.2	32.2	32.9	40.2	33.6
III	43.9	35.1	41.7	27.8	51.9	32.2	35.1	52.6
IV	38.0	109.7	19.7	21.1	54.1	22.6	23.4	27.3
V	51.9	68.7	20.5	19.0	32.2	32.2	22.6	26.3
VI	51.2	39.5	35.9	27.8	27.8	51.9	41.7	28.5
TOTAL	218.7	310.0	160.9	263.4	204.1	200.3	230.3	220.7

	Total.
Sub Block I	283.8
II	304.2
III	320.3
IV	322.4
V	273.4
VI	304.3
TOTAL	1808.4

Not Significant.

TABLE 50.

BLOCK C. pH.

0 - 9" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	TOTAL
Block I	4.90	4.15	5.45	4.25	4.60	4.68	4.55	4.60	37.18
II	4.45	4.50	4.80	4.40	4.55	4.35	4.10	4.45	35.60
III	4.60	4.20	5.00	5.55	5.60	4.45	5.70	5.60	40.70
IV	5.10	5.45	4.90	4.90	4.95	5.00	5.30	4.40	40.00
TOTAL	19.05	18.30	20.15	19.10	19.70	18.48	19.65	19.05	153.48

Not Significant $F = <1$

TABLE 51.

BLOCK C. pH.

9 - 12 " OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	Total
Block I	4.25	4.35	5.00	4.55	5.55	4.70	4.60	5.60	38.60
II	4.50	4.45	4.35	4.50	5.55	4.45	4.65	4.55	37.00
III	4.55	4.35	5.00	5.60	5.55	4.35	5.60	5.70	40.70
IV	4.90	5.00	4.90	4.80	4.90	5.00	5.30	4.35	39.15
TOTAL	18.20	18.15	19.25	19.45	21.55	18.50	20.15	20.20	155.45

Not Significant.

TABLE 52.

BLOCK C. PH.

12 - 24" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
Sub Block I	4.20	4.20	4.25	4.20	4.20	4.40	4.20	4.15
II	4.30	4.40	4.15	4.40	4.30	4.25	4.20	4.20
III	4.05	4.25	4.05	4.20	4.20	4.05	4.25	4.45
IV	4.20	4.40	3.95	4.15	4.00	4.00	4.25	4.10
TOTAL	16.75	15.25	16.40	16.95	16.70	16.70	16.90	16.90

	TOTAL.
Sub Block I	33.80
II	34.20
III	31.50
IV	33.05
TOTAL	132.55

Not significant $F = <1$

TABLE 53.

BLOCK C. pH.

24 - 36" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
Sub Block I	4.30	4.40	4.65	4.42	4.48	5.05	4.55	4.58
II	4.40	4.49	3.90	4.32	4.79	4.95	4.35	4.29
III	4.11	4.20	4.34	4.87	4.61	4.16	4.71	4.69
IV	4.48	4.55	4.15	4.52.	4.30	4.75	4.90	4.33
TOTAL	17.29	17.64	17.04	18.13	18.18	18.91	18.51	17.89

	TOTAL.
Sub Block I	36.43
II	35.49
III	35.69
IV	35.98
TOTAL	143.59

Not Significant.

TABLE 54.

Block B. pH

(9" - 12" OF SOIL).

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	TOTAL
Block I	5.35	4.45	5.70	5.80	5.95	5.00	5.25	4.90	42.40
II	5.45	4.50	5.90	4.70	5.60	5.35	4.50	4.60	40.60
III	5.25	4.25	4.25	5.45	5.35	4.50	5.50	4.70	39.25
IV	4.60	4.60	4.60	5.55	4.60	5.10	5.15	4.70	38.90
V	4.70	4.80	5.00	5.00	4.70	4.55	4.90	5.00	38.65
VI	4.55	4.80	4.70	4.60	4.70	5.25	4.80	5.55	38.95
TOTAL	29.90	27.40	30.15	31.10	30.90	29.75	30.10	29.45	238.75

TABLE 55.

BLOCK B. pH.

9 - 12" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK
Block I	4.95	4.70	5.45	5.25	5.85	5.25	4.70	4.90
II	5.35	4.80	4.80	5.25	5.25	5.15	4.90	4.80
III	4.60	4.45	4.70	4.15	5.15	4.50	5.15	4.45
IV	4.45	4.60	4.70	5.35	4.70	5.10	5.15	5.00
V	4.60	4.60	5.00	4.70	4.80	4.80	4.90	4.70
VI	4.55	4.90	4.90	4.60	4.70	5.00	4.70	5.25
TOTAL	28.50	28.05	29.50	29.30	30.45	29.80	29.50	29.10

Not Significant.

TABLE 56.

BLOCK B. pH

12" - 24" of Soil.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	TOTAL
Block I	4.73	4.55	4.94	4.43	5.42	4.71	4.45	5.09	38.32
II	4.68	4.58	5.11	4.78	4.69	4.71	4.40	4.50	37.45
III	4.40	4.33	4.32	4.08	4.40	4.65	4.40	4.25	34.83
IV	4.50	4.69	5.04	4.38	4.32	4.38	4.43	4.81	36.55
V	4.50	4.83	4.81	5.05	5.03	4.39	4.55	4.53	37.69
VI	4.98	4.85	4.80	4.80	4.80	4.38	4.43	4.30	37.34
TOTAL	27.79	27.83	29.02	27.52	28.66	27.22	26.66	27.48	222.18

Not Significant.

TABLE 57.

BLOCK B. pH

24" - 36" OF SOIL.

	N_1	N_3	N_1P	N_3P	N_1K	N_3K	N_1PK	N_3PK	TOTAL
Block I	4.50	4.30	4.50	4.30	5.00	4.60	4.10	4.15	35.45
II	4.20	3.90	4.80	3.90	4.40	4.25	4.25	4.25	33.95
III	4.30	4.20	4.00	4.00	4.25	4.15	4.15	4.10	33.15
IV	4.30	4.10	4.40	3.90	4.00	4.40	4.50	4.30	34.70
V	4.20	4.50	4.30	4.30	4.20	4.40	4.70	4.50	35.10
VI	4.20	4.70	4.30	4.30	4.30	4.20	4.15	4.15	34.30
TOTAL	25.70	25.50	26.30	24.70	26.15	26.00	25.85	25.45	206.65

Not Significant.

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